AN EVALUATION OF DESKTOP VIDEO CONFERENCING FOR ONE-TO-ONE TUTORIAL SUPPORT IN MATHEMATICS

By

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Abstract

The growth in Flexible and Distributed Learning will, it is believed, lead to a need for a more innovative and flexible approach to the way support is offered to students.

This study which was conducted with students at a Further Education College looks at the effectiveness of using Desktop Video Conferencing (DVC) to provide support to students studying mathematics at a number of different levels.

The research design adopted the concept of triangulation with three different approaches being used.

The first strand of the methodology was the collection of statistical data for all students re-sitting GCSE mathematics to develop a model to predict the learning outcome for students.

The second strand was the extensive use of questionnaires and interviews with students receiving learning support.

The final strand was the application of discourse analysis to recordings of both face-to-face and DVC tutorials in order that a comparison could be made between them. To do this it was necessary to develop a research tool to record both verbal and non-verbal dialogue.

The main conclusion from the study was that there was no identifiable difference in learning outcome between tutorials conducted face-to-face and those conducted using DVC.

A number of positive advantages of using DVC emerged during the course of the study. These included the fact that most students preferred tutorials using DVC as they found the environment less threatening than when sitting next to a tutor. Other advantages resulted from the use of the electronic Whiteboard, these included being able to give students quicker feedback, if appropriate.

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Chapter 1 Introduction

1.1 Background to the research

The European Union (EU) has, since the early 1980's actively encouraged and financed research into the 'Information Society'. In 1986 the EU launched three major research projects into the use of telematics (a word coined in the 1970's to cover the implications for society of the confluence of computing and telecommunications). The three projects were in the areas of healthcare, road transport and distance learning. The third of these was DELTA (Developing European Learning through Technology Advance), reported in the final report of TAP (Telematics Application Programme, Telematics for Flexible and Distance Learning, 1998). Since this first project there have been twenty further projects in this field. The Telematics for Flexible and Distance Learning- Final Report (TAP 1998) provides a summary of these.

The Report by the Commissioners of the European Union, Directorate-General DGX111 entitled "Telecommunications Information Market and Exploitation of Research" implicitly assumes the need for flexible learning and training in order to provide 'lifelong learning' in the future. (Van den Brande, 1993). Flexible learning may be defined as "*...enabling learners to learn when they want (frequency, duration, timing), how they want (modes of learning), and what they want (that is, learners can define what constitutes learning to them)*" (ibid). Underlying the drive for increased flexibility is the assumption that this will lead to increased productivity at three levels; for the learner, his or her employer and the society or region to which the learner belongs. Increased productivity is seen as the key to increased prosperity within the European Community.

More recently in the United Kingdom the Further Education Funding Council (FEFC) has produced a consultative strategy document entitled "Networking Lifelong Learning"(FEFC, 1999). Included in this was a government target to increase the number of students in FE education by 0.7 million by the year 2002, placing a strong bias towards the use of telematics to achieve this. Government statistics show that this target was exceeded with 2.48 million students in FE education for the period 1997/8 rising to 4.99 million for the period 2001/02 (Office for National Statistics, 2003), an increase in excess of 2.5 million.

Another step towards the achievement of the government's targets has been the official launch in April 2000 of the UFI (University for Industry) whose role it is to coordinate the delivery of teaching programmes for much of the increased student population. Between the 1st April 2000 and late 2003 some 880,000 students had registered for courses with 75% of these being delivered online (UFI, 2003).

The UK e-University was also launched in 2000, with the aim of attracting overseas students to study online at UK universities. Unlike the UFI the UK e-University has failed to attract students, with only 900 starting courses in the first four years as against a target of 5,600 for the first year (Computing 2004).

The research programmes funded under DGXIII to develop methods of delivering flexible learning, have coincided with the proliferation of personal computers and more particularly the Internet. It was estimated that by 2003 some 80 million households in Europe would have access to the Internet. In the UK alone the number of households with access to the Internet quadrupled in the period 1998/99 - 2001/02 bringing the total to 40% or 9.6 million, households (Office for National Statistics, 2003).

It now seems probable that increased use of telematics will become one of the main vehicles for transmission of teaching materials and support for students. The nature of these materials seems only to be limited by the imagination of the designers and funding. Some courses currently being offered comprise nothing more than a translation of written texts to Web pages. These can be contrasted with truly interactive web sites such as those developed by Herriot Watt/Cambridge Universities for engineering undergraduates through the Institute for Computer Based Learning (ICBLb, 2002). The Institute for Computer Based Learning web based resources seem to provide a real opportunity for students to construct their own understanding of a subject by investigating the nature of the mathematics, underpinning it within an engineering environment.

The growth of flexible and distributed learning within the UK is thought by the author to be slower than most European Countries; this may in part be due to the presence of a strong Open University (OU). Traditionally the OU has chosen to provide its support through tutorials conducted locally and students being able to access their tutors by telephone. However Rowntree (1995) reports that the university set itself a target to provide computer conferencing for all courses by the year 2000 and reference to the OU's website in 2003 showed that this was now being offered as one of the forms of support available to students. The OU uses one-to-many synchronous communications, using a system called Lyceum. It has not, however taken up by all courses and the OU was unable to tell the author the percentage of courses for which it was being used.

The University for Industry (UFI) on the other hand only currently offers support to students via e-mail with tutors. This would seem to be a lost opportunity to offer computer conferencing, the cost of which continues to fall and which is now accessible to anyone with a home computer and an Internet connection. A number of studies into the use of computer conferencing have been carried out in other countries, particularly Australia and the USA. Details of some of these studies are included in the literature review in Chapter 2.

As the number of students learning flexibly and/or at a distance increases so will the demand for learning support. The new technologies which have evolved over the last decade and which are now widely available offer additional ways in which this can be delivered e.g. e-mail, Computer Conferencing, and Desktop Video Conferencing (DVC).

Whilst all the above methods of support have a place, the author sees the medium offering the most flexibility and potential for one-to-one tutorials in mathematics as being Desktop Video Conferencing (DVC). The model used for the research was based on Laurillard's Conversational Framework (1993), which considers a one-to-one learning environment to be the best. All tutorials conducted by the author at the college where the research was carried out were conducted on a one-to-one basis, the normal practice at this college. It is with an expectation that the need for mathematics tutorial support at a distance will increase in the future that this research has been carried out. DVC may also prove to be an appropriate and effective way of providing support for students in other academic fields and for students with particular types of learning difficulties.

One limitation of the use of DVC at the beginning of this project was the cost of ISDN telephone connections and calls. However during the course of the study these costs were dramatically reduced through increased competition within the telecommunications industry and alternative ways of routing connections. Currently, among manufacturers of DVC equipment there is a trend towards using networks and Internet providers rather than ISDN. With the introduction of broadband networks it is now possible for anyone to have fast access to the Internet at minimal cost and it now seems likely that ISDN will become redundant in the near future.

1.2 What is Desktop Video Conferencing?

DVC is a technique that allows two or more people in different locations to communicate live, or synchronously, using computers that are linked together. The link allows both live audio and live video to be simultaneously transmitted between those participating in the same way as a live news report on television allows a reporter to both talk to and be seen by, the presenter in the studio, and vice versa. Using such methods also makes it possible to transfer computer files between the participants and to enable them to read and process them on a shared basis. DVC is possible with any reasonably modern personal computer fitted with an inexpensive video camera and which has a means of linking to other computers. Such links can be achieved through dedicated computer networks (local, national or international) or telephone lines, using a high-speed modem. The quality of communication is improved by using dedicated ISDN telephone lines or broadband. Adjuncts to communication include e-mail links and the Internet. The effectiveness of these adjuncts varies considerably, depending on the speed and capacity of the server being used and the volume of traffic. DVC can be used between a number of participants; Hearnshaw (1997) used it in the ratio of 1:4 to provide tutorial support to students on an IT course. However Wright and Cordeaux (1996) have concluded that the best use of this technology (DVC) is in situations where communication is one-to-one.

DVC should be distinguished from conventional videoconferencing, which is typically delivered one-to-many (e.g. a lecture given in the University of Plymouth is transmitted to student nurses in a number of locations throughout the southwest) or many-to-many (e.g. the Royal Bank of Scotland using video conferencing to avoid executives travelling to meetings). Both of these types of video conferencing are relatively expensive compared to DVC and may require the use of recording studios and satellite links to achieve an acceptable quality of transmission. DVC should also be distinguished from videophone links, which only offer audio and simple video images and lack the extended range of facilities available with DVC.

The European Community's funded Telematics Application Programme has funded the "Support Action to Facilitate the use of Videoconferencing in Education" (SAVIE) research project. The SAVIE (1999) project has produced a detailed report on how best use can be made of the technology, and includes DVC. The report includes consideration of the choice of equipment, how it should be used and the planning necessary for its effective use. It does not however address the issue of whether DVC provides an effective medium for an academic dialogue to take place.

To date, limited use has been made of the available technology, mainly, it is thought by the author, because of the relatively high cost of the equipment and the high charges on ISDN telephone lines. Its use has predominantly been in the higher education field where it has been used for tutorial support either for small groups or one-to-one (Hearnshaw 1997, Wright & Cordeaux 1996, Jennings *et al.*1997). Whilst the cost of video conferencing systems such as 'Polycom Viavideo' and ISDN telephone costs have not reduced during the course of the research the author is aware of a number of pilot projects now using DVC; these include:

i. DVC telecommunications at Robin Hood School, Birmingham a primary school where the use of DVC has been explored. Projects undertaken included a collaborative Arts project with Exeter University, which was intended to increase pupils' awareness of art (Becta, 2001).

ii. Innovative ICT Project (Mathematically Able Students). Exeter College is using this to deliver tutorial support to small groups of students studying 'A' level Further Mathematics at colleges throughout the southwest of England (Stripp, 2002).

iii. The Global Classroom. This is a collaborative project between Jackson University, Florida and Keele University, UK where tutorial support for undergraduate mathematics students is being provided using DVC (Bessman & Quinney, 2000).

1.2.1 What equipment is needed?

At the lowest effective level of implementation, DVC requires the following:

i. A personal computer linked to a communications network - typically this will either be a local area network (LAN) or a telephone link such as an ISDN line or broadband.

ii. A DVC implementation package, comprising software, a video camera and a headset (or speakers and a microphone). Microsoft Windows 98.2 and subsequent versions of the Windows operating system incorporate Netmeeting software that requires only a simple video camera as additional hardware. This represents a potential saving of over £400 on the cost of equipment previously required, although it is acknowledged that the audio and video quality is not as good as that achieved using, for example the Intel Proshare system. Another alternative system is Yahoo messenger; this however does not offer the range of facilities available in Netmeeting.

iii. A Graphics Tablet. This is a device that replicates the action of a mouse and allows hand writing and drawing directly into the computer using a pen facility with appropriate drawing software.

iv. A modem of some form is required for all forms of connection.

During the course of the research the introduction of broadband network connections first in the USA and now in the UK has resulted in the increased use of video conferencing. One of the implications of this is that the way connections are made is now changing; instead of DVC being a direct connection using ISDN telephone lines, links will now be routed through the Internet. Whilst this offers the potential to make the cost of DVC substantially cheaper, the proliferation of firewalls into networks can, at present, pose problems for making connections. This problem is exacerbated by the fact that not all video conferencing systems use the same ports, Netmeeting for example uses dynamic port assignment for the audio transmissions. Microsoft has addressed this problem with the Windows XP service pack 2 by incorporating a firewall specifically designed to permit Netmeeting through it. At present the most effective way of using DVC is seen as having a dedicated computer linked to the Internet via a broadband connection.

1.2.2 How DVC works

A connection between the two computers is made in a similar way to a conventional telephone call. Once the connection has been made a video and audio link is established between the participants and a screen like the one shown in Figure 1.1 appears (the size of the video images can be adjusted up to full screen for the other participant).

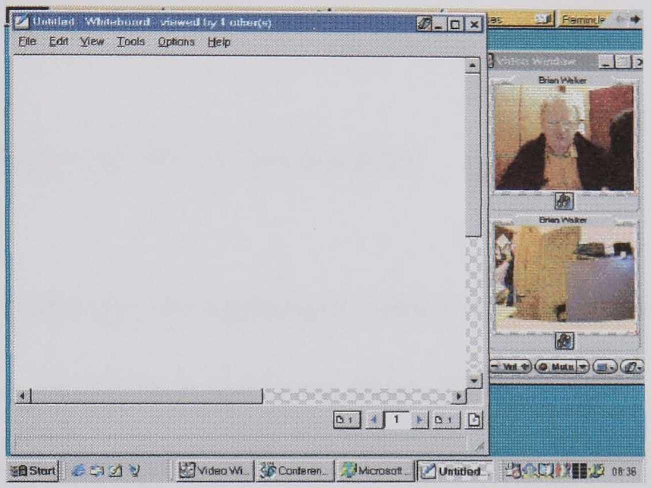


Figure 1.1: Computer screen after connection

When the goals for the session have been set it has been found most useful to enlarge the whiteboard to fill the whole screen giving the maximum area to work on. This has been the experience of others using DVC.

> *Our experience has suggested that the technology can facilitate an approach to learning if preoccupation with the video aspect does not assume primacy as this distracts from moving on into working collaboratively using the data services. The video is useful to establish human contact, create reassurance and assure 'visible' support, but once work begins on an issue or a document the video assumes far less importance* (Wright and Cordeaux, 1996).

The following photograph, Figure 1.2, shows the start of a tutorial with a student at Exeter College, with the tutor at another location (in this instance, Exeter University).

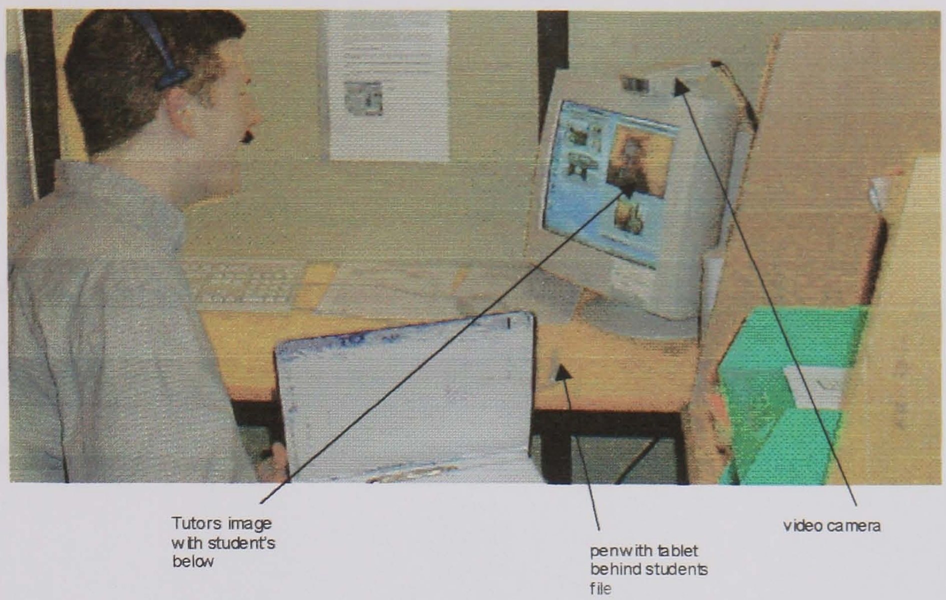


Figure 1.2: The start of a tutorial

Once a tutorial is under way the whiteboard facility becomes the focus of the dialogue. Figure 1.3 below shows a typical whiteboard image from another tutorial.

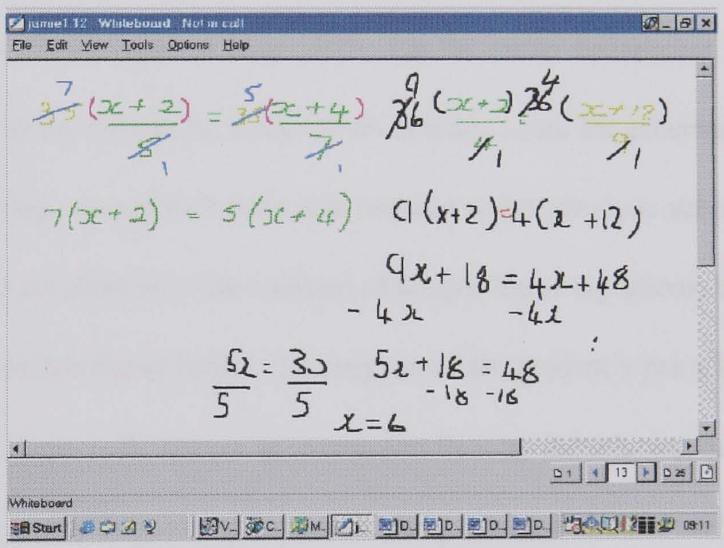


Figure 1.3: Typical whiteboard

The whiteboard can be minimised at any point if it is thought beneficial to restore the video images. The whiteboard incorporates features that would be difficult to replicate in a normal one-to-one tutorial including having a large variety of colours for the pen and highlighter, an electronic pointer that can be moved by either participant, easy correction of errors, and a facility to draw simple shapes. Discussions of the advantages of using a whiteboard are included in Chapter 6. It is also possible to access files and cut and paste from these into the whiteboard to provide questions for students to work on. An alternative to this is file-sharing that allows the two participants to work collaboratively on a document such as a Word file. One of the features of the whiteboard that is seen as being beneficial for tutorials is that the student cannot anticipate what the tutor is going to put on the screen next.

The whiteboards are synchronised which means the participants see the same area of the board and they are able to write simultaneously with each seeing the other's work. This has the inherent advantage that the tutor can see exactly what the student is writing and the speed at which the student is working.

1.2.3 An example of a DVC tutorial

The following images were captured during the first two tutorial sessions (each of one hour) with a student at Exeter College. The student wanted to obtain a grade C at GCSE mathematics in order to enter the Fire Service. He had achieved a grade D at Foundation Level mathematics previously in his GCSE, which he sat in June 1999. On the initial assessment test taken at the beginning of the course at the college he achieved an average score for potential and below average for the numeracy test, which suggested under achievement at his previous school.

The goal for the tutorials was the solution of simple linear equations, taking the topic as far as the student was able within the syllabus. Having tested the student's prior knowledge, first by asking him to solve equations with integer solutions and then by introducing questions where the answers were fractions, it was apparent that he was using a trial and error method. Having discussed with him the need for a systematic approach that would work for any equation, an algorithm was constructed in stages for tackling these types of equations. All writing by the student is in black the other colours being used by the tutor.

The whiteboard reproduced in Figure 1.4 is the first example shown to the student. The question on the left was completed by the tutor, that on the right by the student. This represents the last two stages of the three-stage algorithm being developed i.e. the elimination of any number on the side of the equation where the **x**'s are and then dividing by the coefficient of the **x**. The notation used emphasises that the same must be done to both sides of the equation.

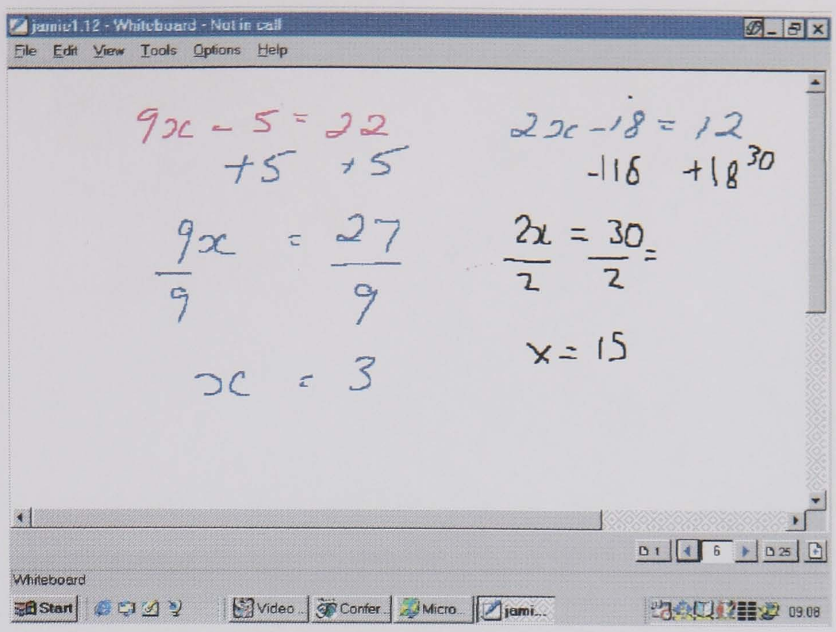


Figure 1.4: First steps in solving an equation

After the student had solved the equation on the right, a new whiteboard was displayed with a new question. This meant that he could not see the example that he had just completed and had to rely on what he had remembered to answer the next question.

Figure 1.5 shows the student's working while attempting the next problem.

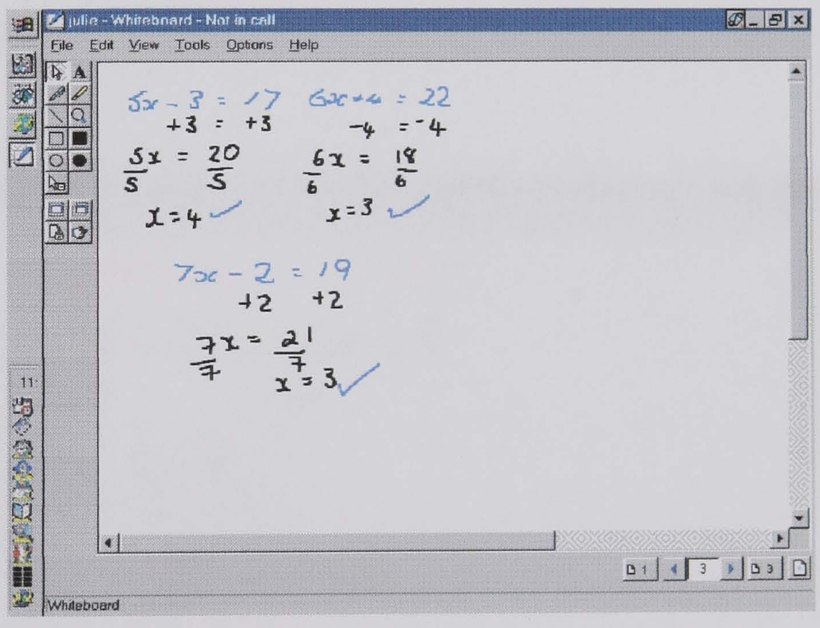


Figure 1.5: Additional questions answered by student

Having successfully completed a number of simple examples, equations with the variable on both sides were introduced. Figure 1.6 shows the final stage of the algorithm. The equation now has the variable on both sides; and the strategy is to remove the smaller number of x's without worrying about which side of the equation the x's are on. The example on the left was completed by the tutor and that on the right by the student. The circled numbers identify the three steps necessary to solve an equation of this type and were discussed with the student as he worked through examples.

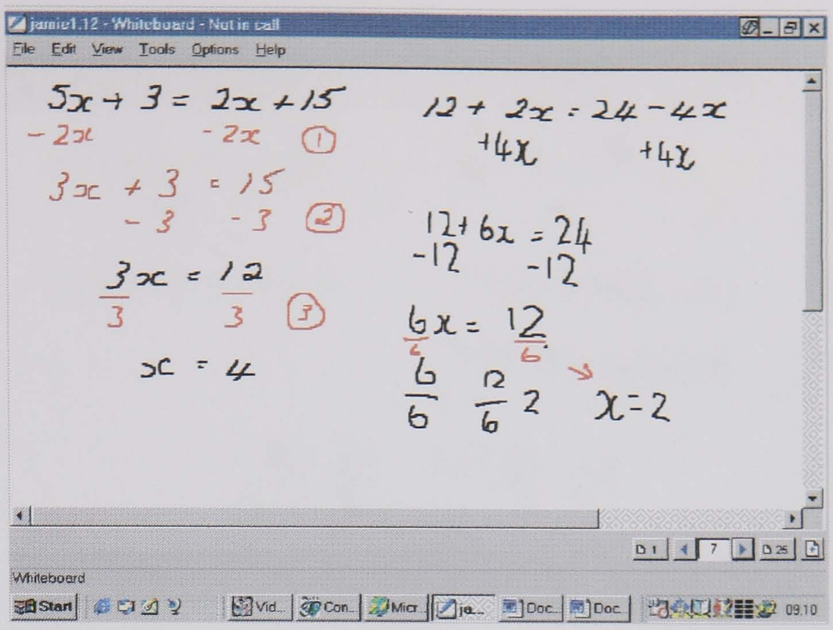


Figure 1.6: The final step in solving an equation

Attention now turned to what operations might be required before the equation could be solved. The strategy here was to remove any brackets and/or fractions and simplify the equation, if necessary, before starting to solve it. First, the problem of removing any brackets was tackled, Figure 1.7 below shows how the tutor was able to prompt and correct the student's work when necessary, the yellow was added by the tutor to indicate how to multiply out the bracket.

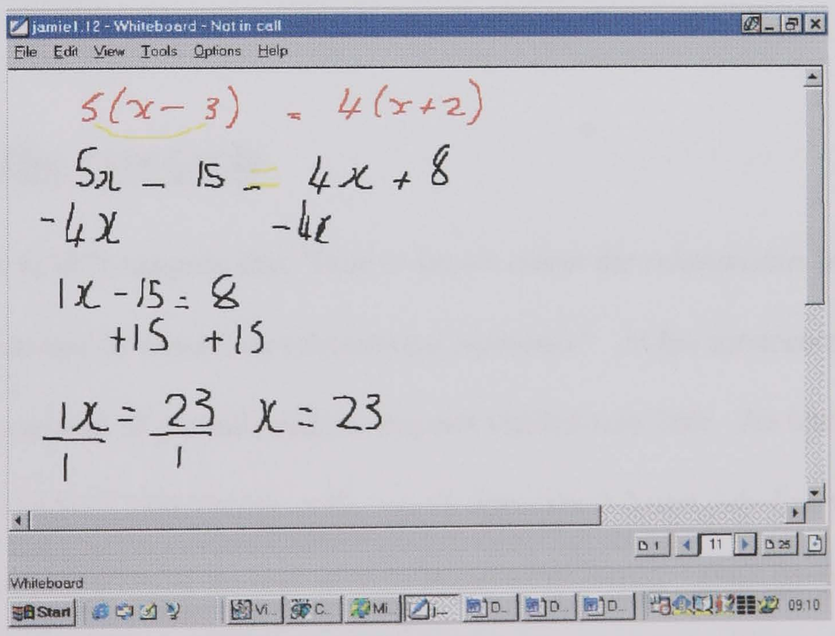


Figure 1.7: Removing the brackets

Finally, fractions were introduced, again with the strategy of first removing them as a preliminary to solution. In Figure 1.8, the left hand side is an example completed by the tutor showing how the fraction can be removed by multiplying by the product of the denominators (without considering the LCM).

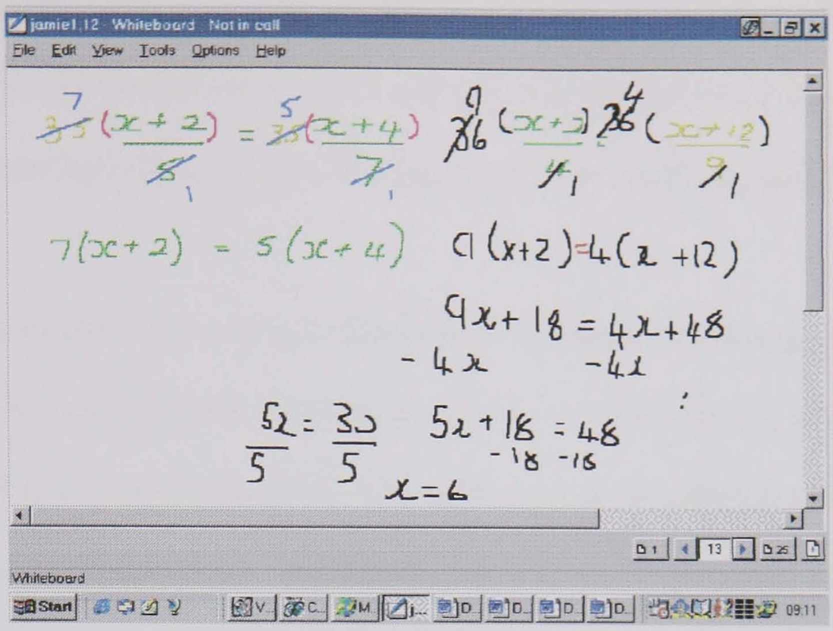


Figure 1.8: Removing the fractions

Based on more than four thousand hours experience by the author of one-to-one tutorials, the outcome of these two sessions was as good, if not better than that which would have been expected from a student with this standard of mathematical background, using conventional face-to-face tutorials. The session that followed recapped on what had been covered in the previous session and then moved on to the solution of simultaneous equations, which again presented no great difficulties for the student.

1.3 Aims of the research

Hearnshaw (1997) suggests that *"little is known about the relationship between the quality of a videoconference and its impact on educational outcomes".* At the commencement of this study in 1997, literature searches of journals and the Internet yielded very little. An Internet search at that time using Desktop Video Conferencing as the search description found only five sites, whereas a similar search performed towards the end of 2003 found 14,600 sites. Although the interest and use of DVC has grown considerably over the period of the study there remain few rigorous evaluations of it as a tool in education.

The primary aim of the research was to assess the effectiveness of mathematics tutoring provided by DVC compared to traditional face-to-face support. At the start of this project no large-scale studies had been carried out in this area. The author was aware of a number of small studies that had been carried out, including one by the School of Education at Exeter University, in which DVC was used to provide tutorial support for student mathematics teachers on teaching practice. Early indications from these research projects were that DVC is equally or more effective than face-to-face tutorials.

The secondary aim was to evaluate and quantify the effect that learning support (either face-to-face or using DVC) had on students in terms of their learning outcomes i.e. how much, if any, of their improved performance (as measured by their mock examination results) could be attributed to their having received learning support. Additionally, the research was broadened to look at the students' learning experience using DVC and to identify any differences that there might be with face-to-face tutorials.

The research was not aimed at providing a technical assessment of the available technology but rather at how well it is able to provide an environment in which effective teaching and learning can take place i.e. how well it is able to provide the environment for an academic dialogue, meeting the criteria of the Conversational Framework developed by Laurillard (1993).

1.4 Location of the research

The research was carried out at Exeter College, where the author was employed (part-time) to provide students with learning support for mathematics on a one-to-one basis. Under the existing arrangements, with regards to learning support referrals a student's tutor or subject lecturer could refer them or alternatively students were able to self-refer.

The positive impact on retention rates through the provision of learning support has been well researched (Basic Skills Agency, 1997). One aspect of the BSA research was to consider the factors that make support successful and whether they differ when the support is provided by DVC. Research amongst mathematics undergraduates in 46 English universities (Lawson *et al,* 2001), suggests that the impact on students of learning support extends beyond that of just academic input, to emotional support and the engendering of a sense of a secure environment in which to work.

Exeter College is the only state funded college of further education in the city of Exeter and its students are primarily drawn from the five feeder schools in the city, (there are also some students from other parts of Devon and a small number of overseas students). Unlike most other larger towns and cities in the region none of the feeder schools have provision for post 16 education although this situation is currently the subject of an enquiry that is considering the future structure of education provision in Exeter. The college also offers courses in Business Studies at HE level. The college has a population of approximately 13, 000 students of whom around 3, 700 are studying 'A' levels or the International Baccalaureate.

All students coming directly from schools where they had not achieved a grade C in the key subjects of English and mathematics are encouraged to re-sit the examinations. The college also offers GCSE re-sit packages for students wishing to generally improve their grades. Each year around 250 students start a re-sit course in GCSE mathematics, for the majority of students this is done within a workshop environment with tutors on hand to help. The students work through a series of subject specific modules written by the college and sit tests at the end of each group of modules.

This form of learning lacks many of the opportunities advocated in the Cockcroft Report (1982) and has consistently produced low retention rates with approximately only 15% of the students completing the course and sitting the GCSE examinations. Following a review and comparison with other FE colleges the system was superseded in 2002 by the use of taught classes and, for some students, computer marked assessments.

1.5 Summary of contents of the thesis

The thesis starts with a literature review, (Chapter2) which covers the following areas:

i. Theories of learning and learning styles.

ii. Discourse Analysis.

iii. Studies of the use of DVC.

iv. Phenomenography and Laurillard's Conversational Framework.

The literature review is followed in Chapter 3 by the rationale for and details of, the methodology that was used and the research tools developed.

Chapters 4, 5, and 6 contain the results and analysis from the three strands of the methodology adopted for the research.

Finally, Chapter 7 brings together the findings of the research, presents conclusions and suggests areas for further work.

1.6 Main outcomes of the research

The research enabled distinct advantages of DVC over face-to-face tutorials to be identified. These advantages are identified in full in Chapter 6 and summarised in Chapter 7. Although students reported noticeable differences between the two types of tutorial, there was no measurable difference in their learning outcomes. DVC enhanced the experience from the students' perspective, but did not improve or detract from their achievements.

Learning support did improve retention rates amongst students in line with other previous research. However, the retention rate amongst students receiving support using DVC was substantially higher than that for students receiving support using face-to-face tuition at Exeter College. This finding must however be treated with caution in view of the relatively small sample.

Through the modification of Laurillard's (1993) Conversational Framework and the addition of discourse analysis, a research tool was developed that was capable of analysing a tutorial to determine its nature and whether it was well structured.

Chapter 2 Literature review

2.0 Introduction

This chapter is divided into four sections, the first reviews the history and development of theories of learning leading to a summary of current thinking, the second section is a review of literature written on the use of DVC and the third considers the construction of Laurillard's Conversational Framework and the background to it. Details of how the Conversational Framework and other aspects of the literature review were incorporated into the research are discussed in Chapter 3. The fourth section looks at discourse analysis and in particular those aspects of it which are appropriate to the analysis of dialogue between a tutor and student.

2.1 Theories of learning

2.1.0 Introduction

An understanding of learning theories was considered to be important if this research was to provide a comprehensive picture of DVC as a medium for conducting tutorials and to allow the dialogue from these tutorials to be interpreted in such a way that any weaknesses in DVC in terms of learning outcomes could be highlighted.

The development of learning theories is, in part, intrinsically linked to the aims of education prevalent at any particular time in a country. As Bruner (1966) said "*I shall take it as self evident that each generation must define afresh the nature, direction and aims of education*". The aims and hence the curriculum developed from those aims, are subject to both socio-economic and political pressure and /or legislation.

The extent to which learning theories have developed in response to these pressures is difficult to assess, unless, like Vygotsky, it is specifically enunciated. He made it clear that his intention was to inculcate the philosophy of Karl Marx into his theory of learning (Bredo, 1997).

Aims of mathematics teaching

A consensus of the aims of mathematics education in England has been summarised by Orton, (1994), as follows:

a) To provide students with useful tools for problem solving.

b) To give students an appreciation of the importance of mathematics in understanding how many of our systems work.

c) To engender a mental discipline in students.

d) To give students an understanding that mathematics is a powerful means of communication.

e) To help students realise that there is pleasure to be derived from an aesthetic appreciation of the subject.

The objectives arising from these general aims are constantly evolving and hence the way they are achieved must be the subject of constant review. Consider for example the use of calculators. Are students expected to do arithmetic operations, including complex ones without them? If so then a 'deep understanding' of these operations is desirable. If, however, calculators are to be used solely for the more complicated calculations, then the need for a 'deep understanding' may be questioned. (Learning styles are discussed later in this chapter). Arguably competence in the use of the calculator may be more desirable which in turn may lead to a different approach to teaching. As Spens argued in the case of logarithms, *"Tools become obsolete and better ones take their place.... There is little profit in spending much time in perfecting the command of a tool which will be rarely used in later years and it is a mistake to delay the introduction of the newer and better tool which has replaced it"* (Spens,1938).

The question could be posed whether too little consideration is often given to the epistemological implications of changes to a mathematics syllabus on the subsequent development of students. To cite one example, consider the use of fractions. Whilst they still form part of the mathematics syllabus at Key Stages 1, 2 and 3, students do not generally gain a good understanding of how to combine fractions and consequently some students studying mathematics for 'A' level and beyond cannot competently handle algebraic fractions. It could be argued that students going on to study mathematics for 'A' level should at that stage be taught how to combine fractions. The author's experience, as an 'A'Level mathematics tutor, suggests that this is not, in fact the case.

2.1.1 A division of learning theories

What emerges from a review of learning theories over the period of the 20th century is a picture of an evolving science that has yet to form any consensus about how the process of learning takes place and consequently provides few, if any, answers to the question of how teaching and learning can be most effectively conducted.

At a practical level it means that teaching methods centred on one extreme or the other will in the case of the behaviourist produce individuals who are unthinking doers, and in the case of cognitivists produce impractical thinkers. On a theoretical level it makes it difficult to see the relationship between mechanical skills, such as riding a bike, and abstract learning, such as determining the centroid of a three-dimensional construct. It may well be that an understanding of the concept of centre of mass may make it easier to learn to ride a bike. This polarisation excludes such considerations.

A further split arises from the psychological and sociological aspects of learning, as on the one hand psychologists tend to focus on the individual whilst sociologists focus on groups. Since it is psychologists who tend to focus on theories of learning this has led to theories that have a strongly individualistic bias.

> *Too often, human learning has been depicted in the paradigm of the lone organism pitted against nature... Whether in the model of the behaviourist's organism shaping up responses to fit the geometries and probabilities of the world stimuli, or in the Piagetian model where a lone child struggles single-handed to strike some equilibrium between assimilating the world to himself or himself to the world.* (Bruner, 1983).

This dichotomy has led researchers to look for an alternative approach, which falls under the broad heading of situated learning.

Situated learning

Eminent in this field of research were Piaget, Vygotsky and Dewey. The work of these three researchers undoubtedly made a considerable impact in their day and continues to influence current thinking. Vygotsky's work was not readily available outside the Soviet Union until the 1960's but since then it has become very influential.

Dewey

Functional psychology flourished in the USA at the beginning of the 20th century and pre-eminent amongst the scientists working in this field was John Dewey. Functionalism attempted to integrate thinking and behaviour. Mental life was seen as both the product and producer of evolution; the mind was viewed as a function of the brain and functional psychology investigated the practical functions of the mind in human adaptation.

Functionalists focused on activity and on the process of forming an act (meaning the interaction between environment and a human organism) thus avoiding the usual divisions in learning and development theories i.e. the nature or nurture debate. Is a human organism's development due to innate internal structures or as a consequence of its exposure to an environment?

Interactive learning

The Functionalists' emphasis on interaction served to shift attention away from learning as an adaptation to the demands of a fixed environment and did not pay attention exclusively to what a teacher defined as learning. When the desirability of such interactions is translated into educational terms it implies that learning comes from solving problems that are purely the learner's own, from his or her own experienced uncertainties. Dewey suggested that this meant creating environments in which learners can be stimulated or motivated by, for example, experiencing unexpected difficulties in a routine yet at the same time not being overwhelmed by the difficulty of the situation. Such a situation might arise when re-arranging equations when the variable to be made the subject appears twice in the equation when it has only previously appeared once. The student may realise how to deal with this situations or may require some input from a teacher, in either case the author's experience suggests that students are able to cope with this unexpected difficulty. Being overwhelmed would be likely to lead to the student acting impulsively rather than thoughtfully. This idea is similar to Vygotsky's "Zone of Proximal Development" (ZPD), which is discussed later.

Functional psychologists placed great emphasis on continuity. This meant an emphasis on smooth growth in all aspects of development. They were concerned with understanding the ways in which a developmental process moves from one point to another. In educational terms, Dewey (1916) suggested that educational experiences should lead to growth, to an enhanced ability to extract meaning from experiences. This greater understanding of meaning could then be applied to new experiences. This suggests that a learner does not maintain a rigid mental structure but rather this structure is growing, evolving and being modified continuously. Dewey's two criteria on educative experience, namely interaction and continuity, are interdependent. He believed that inquiry and dialogue were the best ways to promote long-term growth making the present learning more meaningful. Thus the end and the means of education were the same for Dewey (Phye, 1997).

When applied to learning theory this suggests that learning and development can and should occur together. This view differs from that of both Vygotsky and Piaget. Vygotsky argued that development follows learning whilst Piaget argued that development must precede learning.

Dewey was amongst the first to reject the traditional idea of education as transmission of knowledge in favour of the idea that learning requires the active participation of the learner. Dewey, like the other Functional Psychologists attempted to integrate thinking and behaviour, concentrating on the dynamics of action; considering thinking to be a form of action.

Dewey argued that a sensory input must be considered in the context of the ongoing activity and could not be separated from it. Thus rather than thinking that a sensory input comes before action, he thought that it was better to consider the "sensorimotor co-ordinations". In this model the sensory input acts on the "motor action" which in turn acts on the sensory input, thus a cycle is formed between the sensory input and the motor output, for example tennis is (largely) a sensory-motor skill.

Dewey's emphasis was on organism-environment transactions or cycles. His model used the idea of the organism "trying" to modify the environment, which in turn modifies the organism until some form of result is achieved. He viewed the organism and the environment as being partners in an act, the organism and environment continuously changing. Habits would then ideally be able to do the job under varying conditions, and not as a rigid entity. As Dewey said:

> *The fact is that stimulus and responses are not distinctions of existence, but technological distinctions, that is, distinctions of function, or part played, with reference to reaching or maintaining an end... it is only the assumed common reference to an inclusive end which marks each member off as stimulus and response, that apart from such reference we have only antecedent and consequent; in other words, the distinction is one of interpretation.* (Dewey, 1896).

Dewey believed that any attempt to find a relationship between a sensory input and a response, which does not consider the organism and what it is doing at the time, is doomed to failure. Dewey considered that thinking was not a separate stage that came between the sensory input and an organism's response to it. If it were, he argued, this would lead to periods of passive thought between the sensory input and the response.

He rejected the contemporary view of the pupil at the beginning of the 20th century, which he summarised as:

> *The very word pupil has almost come to mean one who is engaged not in having fruitful experiences but in absorbing knowledge directly. Something, which is called mind or consciousness, is severed from the physical organs of activity. The former is then thought to be purely intellectual and cognitive; the latter to be an irrelevant and intruding physical factor. The intimate union of activity and undergoing its consequences which leads to recognition of meaning is broken; instead we have two fragments: mere bodily action on the one side, and meaning directly grasped by "spiritual" activity on the other.* (Dewey, 1916).

For example, whilst there may be periods of quiet thought or reflection during a problem solving situation the thinking may not be passive. The process may require redefinition of the problem and testing tentative solutions. Consider the pupil who is asked to evaluate $\int x \ln x dx$.

They may recognise that because it is a product it must be done using integration by parts but may then misidentify which part of the expression is to be considered as the derivative. If they choose $\ln x$, they might then realise that they do not know how to integrate $\ln x$ and so are unable to complete the operation and need to start again but this time taking x as the term to be integrated.

Dewey's view of learning was of that of an active process and this interpretation also extended to his view of the role of habits:

> *A habit means an ability to use natural conditions as means to ends. It is an active control of the environment through control of the organs of action... if we think of a habit simply as a change wrought*

in the organism, ignoring the fact that this change consists in the ability to effect subsequent changes in the environment, we shall be led to think of "adjustment" as conformity to environment... Adaptation... is quite as much adaptation of the environment to our activities as of our activities to the environment. (Dewey, 1916).

If, as in the view of Dewey, both the environment and the organism are constantly changing then habits are not adaptations to a fixed situation but must be capable of adjusting to the particular circumstances existing at the time. This will form a cyclic process, which is represented by figure 2.1 below. Consistent with this view:

> *Dewey emphasized learning in the context of a larger practical activity, rather than as isolated skills, so that habits perform their functions under realistically varied circumstances. He also emphasized the close involvement of thinking in forming such habits, with thinking stimulated by genuine problems emergent in activity, rather than simply addressing externally abstract problem.*
> (Phye, 1997).

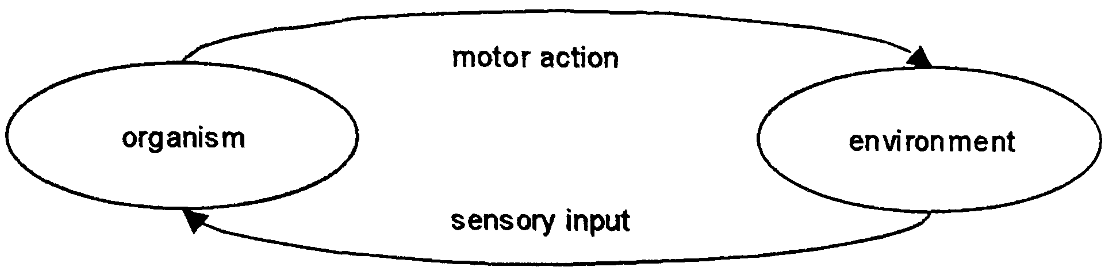


Figure 2.1:Dewey's cycle of transactions

Learning by doing was at the heart of Dewey's method of education. Together with his wife he started the Laboratory School at the University of Chicago where children were given freedom to learn according to their needs and experiences. It was " *the reconstruction or reorganisation of experience which adds to the meaning of experience and increases the ability to direct the course of subsequent experience*" (Dewey, 1916).

Functional psychologists were the first (in the western world at least) to dismiss the idea that pupils were passive receptacles for knowledge; but instead were active participants in the process of learning. The implications for the conduct of lessons conducted were profound, although there still remain institutions, notably universities, where the use of lectures to large groups maintains the pre-functionalist model of education.

The other major contribution that functionalists made to learning theory lies in their identification of the social nature of learning. Whilst these ideas are not unique to them and bear many similarities to the work of Vygotsky they must be recognised as a major contribution to current thinking on the nature of learning.

Piaget

During his long working career the emphasis of his thinking on development and learning changed. His early and middle periods were mainly within the cognitive category, based on the belief that "*human behaviour can be studied free of cultural variability*" (Rowlands 2000). His later work is perhaps more correctly categorised as 'situated', that is based on the belief that learning must be considered in the social situation within which the teaching and learning occurs.

His aim was to produce a coherent model of human cognition and its development and in so doing identify the changes that take place in a person's mental make-up during the course of their lives. He was "*profoundly influenced by Kant's insight that whatever we call knowledge is necessarily determined to a large extent, if not altogether, by the knowers ways of perceiving and conceiving*" (von Glaserfeld, 1995).

He maintained that like all biological entities, the human organism is born with characteristic internal organisation, invariant structures which are responsible for the unique mode of functioning of an individual, which does not change over time. The interaction of the invariant structures with the environment leads through the process of adaptation defined as "*fitting in with- and thriving in- the environment*" (Sylvas and Lunt 1982), to the creation of "*variant cognitive structures*", or sets of schemes (schema).

Adaptation

Piaget believed that all intelligent organisms organise their experiences and adapt to changes in their environment. In his view, adaptation had two components, assimilation and accommodation. Assimilation may be described as the process by which new information is taken in and incorporated into existing schemas, whereas accommodation is the process by which existing schemas are modified to better fit the environment. Whilst one is not necessarily the inverse of the other, they are when equilibration occurs, (equilibration being Piaget's term for the process where a child achieves a balance between taking in new information and modifying existing concepts to accommodate it (Sutherland 1995)). For Piaget "*intellectual adaptation like every other kind consists of putting an assimilatory mechanism and a complementary accommodation into progressive equilibrium*" (Piaget, 1953). Accommodation is Piaget's term for the modification of existing concepts in the light of new experience (Sutherland, 1995). "*Piaget has stressed many times that the most frequent cause of accommodation is the interaction and especially linguistic interaction, with others*" (von Glaserfeld, 1995).

Figures 2.2 and 2.3 illustrate von Glaserfeld's interpretation of the process of adaptation. Figure 2.2 shows the general relationship between learner and environment while Figure 2.3 provides the detail of the process of adaptation.

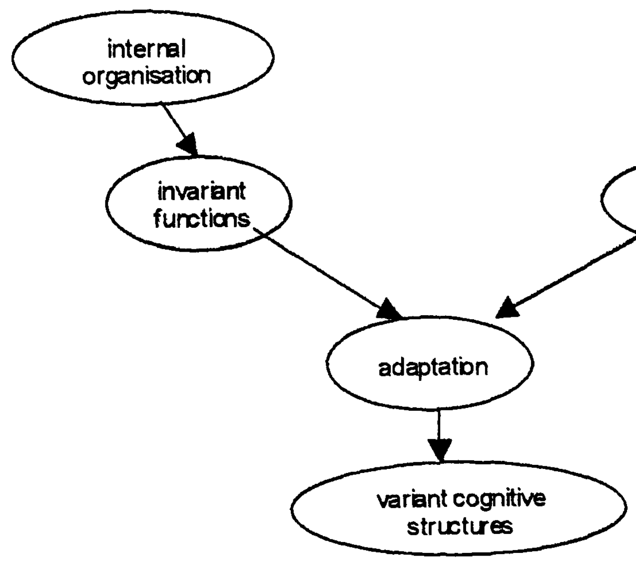


Figure 2.2: The relationship between learner and the environment

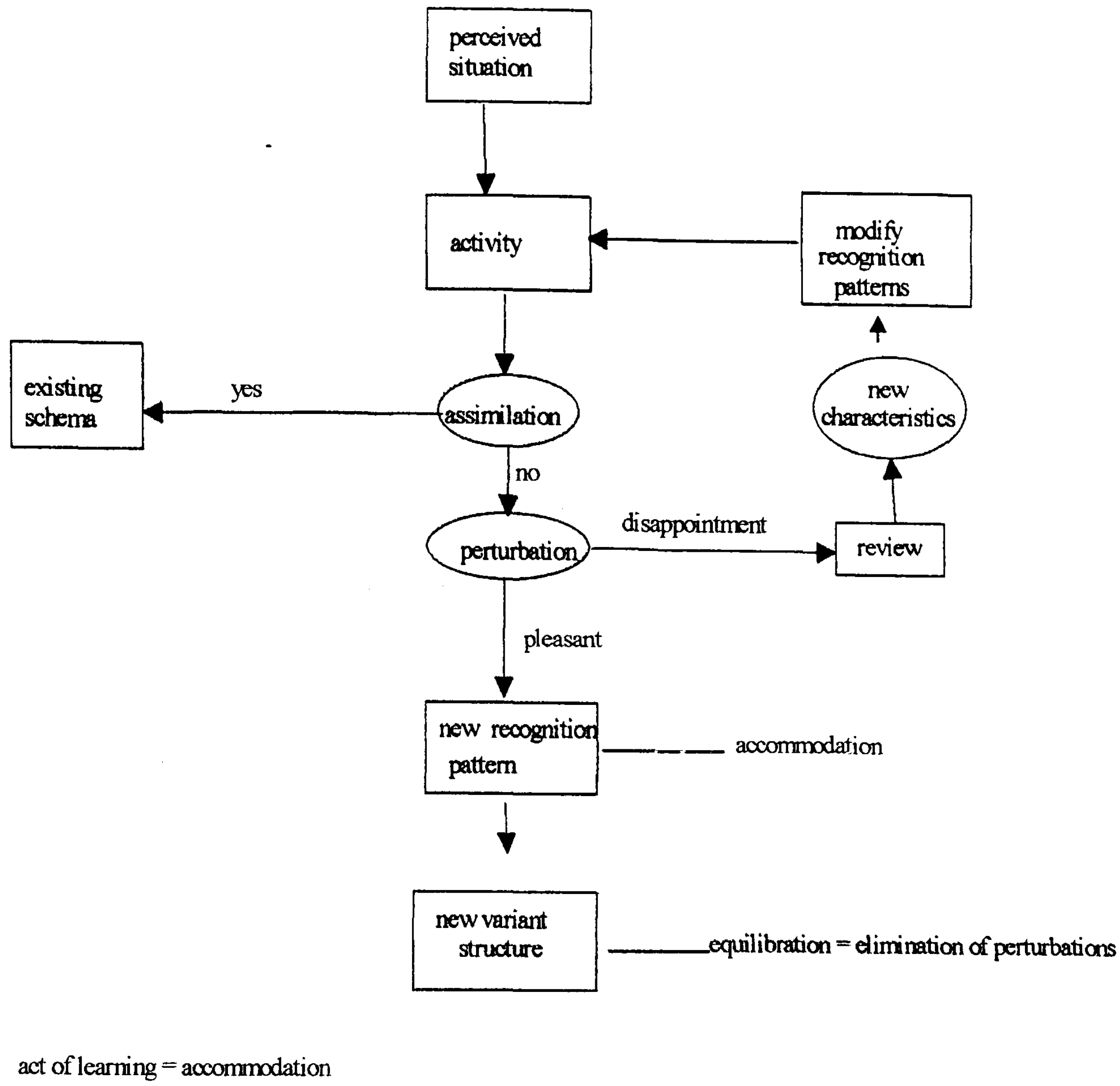


Figure 2.3: The process of adaptation

Piaget identified four main stages of development as follows: -

1) The Sensorimotor stage (age 0-2)

At this stage there is no distinction between perceiving a thing and acting in response to it; thought is literally action. This stage of development is characterised by action patterns.

The sensory-motor stage is said to have ended when the infant is able to represent what he knows symbolically, so that what he knows is no longer tied to what he does. To be able to think symbolically means that the child must be able to represent an event in his mind and internally reflect on it. The child's world is extended in that he can think of something that was present or will be present.

2) The pre-operational stage (age 2-7)

In this stage Piaget believed that a child's thinking would be fundamentally flawed because they cannot yet perform what he called operations. Typically:

a) The child is unable to conceive of any way of experiencing objects other than his own.

b) The child is egocentric and is unable to consider two aspects of the same situation simultaneously.

c) The child is unable to reverse thinking to resolve a problem.

d) Failure to conserve for example when comparing physical size after distorting an object.

3) Concrete operational stage (age 7-11)

During this stage a child's thoughts become less egocentric and more reversible so that it is able to consider several aspects of a situation. He begins to develop coherent cognitive schemes, which are initially sequences of actions. Concrete operational rules replace the pre-operational tendency to rely on intuition and perception.

4) Formal operational stage (age 11 +)

Extends the concrete stage so the child becomes able to combine ideas and becomes aware of the interrelationship of different variables in a situation: *"Thinking becomes formal as soon as it undertakes the coordination of concrete groupings into a single system...because it deals with possible combinations and no longer with objects directly"* (Piaget, 1958). Not all adults are able to think in a formal operational way.

Whilst the age at which a child progresses from one stage to another may vary the sequence is invariant. This invariant sequence represents a progression from simplicity to mature, logical intelligence. To Piaget, intelligence was thus not the outcome elicited by an intelligence test but rather the kind of mental activity that enables adaptation to the demands of the environment.

Although Piaget maintained that the stages of development are clear-cut, researchers such as Bryant (1974) believe that the stages are more blurred. A stepwise sequence of development may be the result of the particular experiments devised by Piaget rather than biological patterns of development of the child. (Sylva & Lunt,1982).

Vygotsky

The Russian psychologist Vygotsky worked in Russia following the revolution of 1917. Vygotsky's interest lay with the social development of mind. Whilst being acquainted with the work of the psychologists of his time, he drew on the work of the philosopher Karl Marx for the idea that peoples' lives are shaped by the social activities in which they participate (Moll, 1990).

There is evidence to suggest that Vygotsky's goal was to make psychology into a science (Rowlands 2002). Shortly before his death he defined the central unit of analysis of psychology as being the emotional experience which he defined as:

> *A unit where, on the one hand in an indivisible state, the environment is represented i.e. that which is being experienced – an emotional experience is always related to something which is found outside the person - and on the other hand, what is represented is how I, myself am experiencing this.* (Vygotsky, 1994).

The impact that Vygotsky's work has had on educational research must be tempered by the fact that early translations of his works were mainly by academics in the United States of America and were heavily edited to remove references to communism and communists (Gillen, 2000).

In his work, Vygotsky drew a clear distinction between complexes (pseudo concepts) or spontaneous concepts and scientific (academic) concepts.

> *Vygotsky's discussion of scientific and spontaneous concepts may be seen as an attempt to analyse the relationship between everyday concepts that are formed in the process of social development of the child, and concepts that exist independently of the child (concepts that exist within a system of concepts) but have yet to be constructed by the child, facilitated by the teacher, as a psychological process of enculturation.* (Rowlands, 2000).

He saw complexes as arising from empirical connections that emerge through an individual's experience and occur at the concrete level of thinking rather than abstract-logical. On the other hand scientific concepts exist at the abstract-logical level and have their "source in school *instruction*"(Vygotsky, 1934/1987). He emphasised two aspects of instruction, which distinguish scientific concepts; one was the development of conscious awareness and the other was voluntary control of knowledge.

He described the convergence of the two types of concepts as follows: scientific concepts grow down into everyday life, into the domain of personal experience, acquiring meaning and significance, and in so doing blaze the trail for the development of everyday concepts upward toward the scientific and facilitate "*mastery of the higher characteristics of the everyday concepts*" (Vygotsky, 1934/1987).

Vygotsky (1981) claimed that the intellectual skills children acquire are directly related to how they acquired them, for example how they interact with others in problem solving activities. Social interactions are mediated through other means such as language and most particularly speech. It is these tools that give us the ability to develop at an abstract level.

The basic assertion of his theories is that mental activity is uniquely human. It is the result of human socialisation and the internalisation of signs and relationships. One of Vygotsky's major studies was the Uzbekistan investigation, which confirmed the hypothesis that "*semiotic mediation systems act as determinants of higher mental process, social relationships and culture are the source of the mind, the working brain only its organ, and the unique social activity of each subject, and how it originates*" (Moll, 1990).

He did not believe that:

> *Primitive man had concepts; abstract, generic names are completely alien to him. He uses the word differently than we do.... All the characteristics of primitive man can be reduced to this main fact, that is, to the fact that instead of [conceptual] notions it operates with complexes.* (Vygotsky & Luria, 1930/1993).

Vygotsky argued that higher mental functions originate through participation in social activities; hence the social context of learning is critical. "*The development of everyday concepts has to be at a certain level before the acquisition of scientific concepts.*" (Rowlands, 2000). Vygotsky's "General law of Cultural Development" states that:

> *Any function in the child's cultural development appears twice, or in two places. First it appears on the social plane, and then on the psychological plane. First it appears between people as an inter psychological category, and then within the child as an intra psychological category.* (Vygotsky, 1981).

Zone of Proximal Development

Vygotsky's Zone of Proximal Development (ZPD) is based on the general concept that learning takes place through social interaction and can be stated as the difference between "*actual developmental levels as determined by independent problem solving [and his] potential development as determined through problem solving under adult guidance or in collaboration with* *more capable peers*"(Vygotsky, 1978). The ZPD has a duality in that it provides us with a concept of how learning takes place and a methodology that can be applied to the learning process. Particularly in the area of mathematics the ZPD provides us with a clear guideline for the complexity and difficulty of problems we set for students. In general this will mean that the problems we ask students to work on independently will be easier than the problems given to a student when working with a tutor or a more experienced peer.

The relationship between learning and development, which is crucially important to educators, was highlighted in Vygotsky's work. Unlike Piaget who considered that maturity was a precondition for learning, Vygotsky held that the development process was "*towed*" by the learning process. "*Thus the notion of a ZPD enables us to propound a new formula, namely that the only "good learning" is that which is in advance of development*" (Vygotsky, 1978). He considered that learning could take place at any time and development did run in parallel to instruction. The instruction a student has received may be many steps in advance of understanding, but when:

> *The child has finally understood something, finally learned something essential; a general experience has been clarified in this 'aha' experience. We have seen that instruction and development do not coincide. They are two different processes with very complex interrelationships. Instruction is only useful when it moves ahead of development. When it does it impels or wakens a whole series of functions that are at a stage of maturation lying in the zone of proximal development. This is the major role of instruction in development.* (Vygotsky, 1987).

There exists one fundamental difference between the theories of Dewey, Piaget and Vygotsky. When cognitive development, defined as "*the growth of the ability to act* " (Sutherland, 1995) occurs, in relationship to learning, Dewey considered learning and development to occur together. "*When applied to learning theory this suggests that learning and development can and should occur together and are preferably inseparable*" (Phye, 1997).

Piaget believed learning follows development.

> *Piaget also studied the cognitive development of children independently of their schooling. The child's own thinking should be studied in isolation from school knowledge, Piaget maintained. He, thus, tried to separate teaching from cognitive development. The conclusions and understandings of the child, his representation of the world, (his) interpretation of physical causality, (his) acquirement of logical forms of thought and abstract logics, are seen by the researcher as if these processes proceeded by themselves, without any influence from instruction in school* (Vygotsky, 1962).

> *Vygotsky explained that the rationale behind Piaget's approach is the idea that we should investigate the child's thinking, excluding all superficial knowledge taken over from adults, and thus laying bare its pure, undistorted development. In his opinion this attitude amounted to claiming that teaching has nothing to do with cognitive development and, ultimately, to the idea that teaching should follow (the maturation of) cognitive development.* (van der Veer & Valsiner, 1994).

Finally, Vygotsky was of the belief that learning precedes development.

> *We have seen that instruction and development do not coincide. They are two different processes with very complex interrelationships. Instruction is only useful when it moves ahead of development. When it does, it impels or wakens a whole series of functions that are in a stage of maturation lying in the zone of proximal development. This is the major role of instruction in development.* (Vygotsky, 1987).

In practical terms the implications for education must be whether it is right to force the pace of education for a pupil or whether the pace of education should be set by the student.

Constructivism

The fundamental principle of constructivism, as defined by von Glaserfeld, is that learning is a constructive activity that students have to carry out for themselves (Fosnot (ed), 1996).

The goal of learning is concept development and deep understanding. Rather than viewing developmental stages as the result of maturation, they are understood by constructivists as "constructions" resulting from active learner reorganisation, which Piaget called variant cognitive structures.

Underlying constructivism is the belief that an individual has no access to the ontological world (i.e. the real world that may exist), but that their knowledge is what they construct. Constructivism draws on Piaget's concept of adaptation; knowledge is not a copy of reality but what von Glaserfeld describes as 'viable' to the individual and arises from actions and the individual's reflection on their actions. The conceptual constructs built up by different individuals are not entities that can be shared. It is not possible to say that two people have the same construct. The best that can be said is that they appear to act in the same way. Construction is a continuing process "*one sees no ground why it should be unreasonable to think that it is the ultimate nature of reality to be in continual construction instead of consisting of an accumulation of ready-made* *structures"* (Piaget in Inhelder and Chapman, 1976). Piaget also emphasised the idea of building on existing structures. *"No behaviour, even if it is new to the individual, constitutes an absolute beginning. It is always grafted onto previous schemes and therefore amounts to assimilating new elements to already constructed structures (innate as reflexes are, or previously acquired)".* (Piaget in Inhelder and Chapman, 1976). Disequilibration may be caused by the social interaction of individuals, which in turn leads to new adaptations and hence learning.

The Zone of Proximal Development, (ZPD) proposed by Vygotsky gives a teacher working within the constructivist paradigm boundaries within which to operate. If the work is too easy then development will not take place but on the other hand if the work is too difficult (even with the help of a teacher) then development again will not occur. A teacher must therefore work at a level appropriate to the student.

Constructivism is polarised between radical and social theorists (Fosnot, 1996). The important issue would, as Fosnot (1996) points out, seem to be the balance between the cognitive individual and culture in the learning process.

Implications of constructivism for teaching

Fosnot, (1996) has identified five implications for teaching, which can be summarised as:

1) Learning is development; it requires action on the part of the learner, hence teachers need to encourage students to ask questions, generate and test their own ideas.
2) Disequilibration encourages learning; errors are then a result of the learner's conceptions and should not be minimised or ignored. Open-ended investigations are therefore to be encouraged. (Disequilibration is a word coined by Piaget meaning a disturbance that creates a tension by its variability and flux, it is the most significant factor for propelling the equilibration cycle to reorganise its structures. It is a force that creates an obstacle to the assimilation of stimuli. (Piaget, 1985)).
3) Reflective practice that may take the form of writing or discussion will lead to learning.
4) Discussion encourages thinking.
5) Learning leads to the development of structures.

For von Glaserfeld, (Jaworski ed, 1994) the implication of constructivism is the need to differentiate between understanding (teaching) and repetition of behaviours (training). Fundamental to von Glaserfeld is the need for teachers to understand that knowledge cannot be transferred. Further, he feels that the educator needs to focus on what is going on inside a student's head rather than on overt responses given by the student. One way in which a teacher can do this is to analyse mistakes made by a student, as these errors reflect how a student understands a concept or idea at a particular point in time. Finally, von Glaserfeld argued that teachers need to not only understand students' conceptual structures but also have ways of modifying them (Jaworski, 1994).

2.1.2 Learning styles and approaches

Introduction

If a tutor is to work from the premise that a student's learning is an active, changing process then an understanding of where a student may be in that learning process at any given time is essential. While it may not always be possible to do this, an appreciation of the possible styles and their implications for learning should help the tutor be more in tune with the needs of the student and therefore deliver better tutorials.

Styles of learning

Kolb's learning style inventory is based on established learning theories. In particular Piaget's ideas of assimilation and accommodation which views intelligence as the balance between the process of adapting concepts to fit the external world (accommodation) and the process of fitting observations into the world of existing concepts (assimilation). Additionally, the inventory draws on two essential creative processes identified by Guilford's Structure-of-Intellect Model. (Kolb,1985).

The four learning styles as defined by Kolb et al, (1979) are:

i. Converger, who can be classified as someone who wants to solve a problem and who relies heavily upon hypothetical-deductive reasoning...to focus on specific problems.

ii. Diverger, who can be classified as someone who solves problems by viewing situations from many perspectives and who relies heavily upon brainstorming and generation of ideas.

iii. Assimilator, who can be classified as someone who solves problems by inductive reasoning and ability to create theoretical models.

iv. Accommodator, who can be classified as someone who solves problems by carrying out plans and experiments…and adapting to specific immediate circumstances.

Kolb, (1984), proposed a theory of experiential learning in which learners progress through a learning cycle in which experience leads to observation and reflection which in turn leads to concept formation. The development of new concepts then leads to new experiences and further experimentation, in a cyclic manner.

The four kinds of learning contexts required by the learning cycle are situated in a one-to-one tutorial:

i. Concrete experience: students are given the opportunity to and encouraged to become involved in new experiences such as tackling different types of problems.

ii. Reflective observation: students are able to reflect on their experiences from different perspectives, and receive constructive feedback from the tutor.

iii. Abstract conceptualisation: students are able to form and process ideas and concepts and integrate them into logical theories.

iv. Active experimentation: students must be able to use ideas and concepts to solve new types of problems, which then takes the learner back to the start of the learning cycle.

Effective learners tend to proceed through all four stages but may develop dominance in one domain (McLoughlin, 1999). Figure 2.4: shows Kolb's learning cycle.

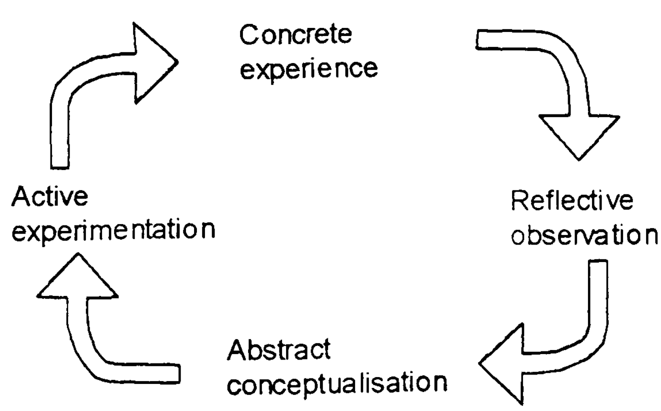


Figure 2.4: The learning cycle proposed by Kolb (1984)

The four phases of the learning cycle are linked to learning styles. Wolf and Kolb (1984) suggested that learners develop different learning styles that emphasise a preference for some modes of learning over others. For example a converger is likely to favour a learning cycle of abstract conceptualisation and active experimentation. It should be noted that while students may at any one time prefer one learning style to another they will also move between learning styles. As Kolb (1979) states "*actual process of growth in any single individual….probably proceeds through successive oscillations from one stage to another*".

Figure 2.5: shows the relevant position of each learning style within the learning cycle.

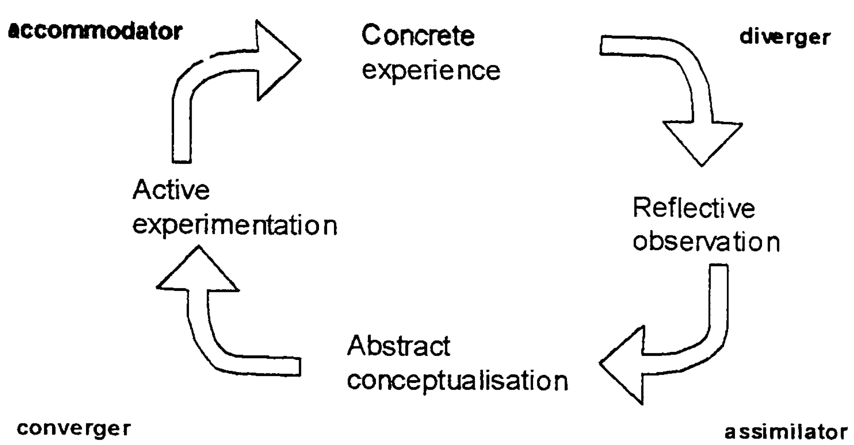


Figure 2.5: Kolb's learning cycle and learning styles

Research conducted by Honey and Mumford, (1992) modified Kolb's learning cycle and proposed four learning styles that corresponded to each of the stages.

Those with the Activist learning style like new experiences and tackling new problems and quickly go on to new tasks to ensure novelty. These learners relate to the 'Concrete Experience' stage of Kolb's cycle. The Pragmatist learning style is for those learners who like to apply new ideas immediately, this learning style relates to the 'Active Experimentation' stage of Kolb's cycle. The learners with the Reflector learning style like to consider all the aspects of a problem before making a decision. This relates to the 'Reflective Observation' stage of the cycle. Finally there is the Theorist learning style for those learners who integrate their observations into conceptual models. This learning style relates to the 'Abstract Conceptualisation' phase of the cycle (McLoughlin, 1999).

Figure 2.6 shows a diagram, which combines the learning cycle of Kolb with the learning styles of Honey and Mumford.

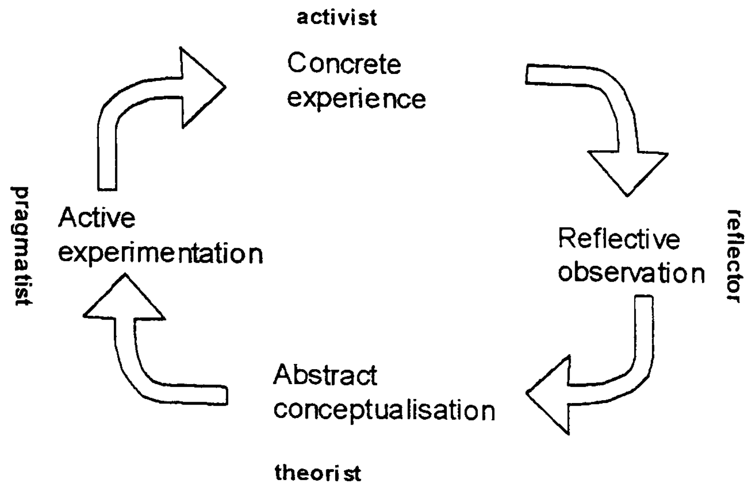


Figure 2.6: Honey and Mumford's learning styles with Kolb's learning cycle

Approaches to learning

Research by Marton and Saljo, (1976), Ramsden, (1992), Biggs, (1987, 1993) and Entwistle, (1981) amongst others has looked at students' approaches to learning and attempted to identify what factors were associated with academic success and failure. From this research five conceptions of what learning means to a student have been identified. In the first of these conceptions, students see learning as a quantitative increase in knowledge, acquiring information or knowing a lot. In the second conception, students view learning as memorising or storing information that can be reproduced as and when required. The third conception has students seeing learning as acquiring facts, skills and methods that can be retained and used as necessary. The fourth conception has greater depth, with the students regarding learning as making sense or abstracting meaning. Further, for students with this conception, learning involves relating each part of the subject matter to other parts and to the real world. The fifth conception has the greatest level of sophistication, with the students seeing learning as interpreting and understanding reality in a different way, comprehending the world by re-interpreting knowledge (Atherton 2003). Students who identify with the first three are categorised as 'surface' learners and those who identify with the last two are categorised as 'deep' learners.

Surface learners

Students who adopt a surface approach to their studies tend to progress through a course and pass examinations and assignments by reproducing memorised material. These types of student will study without reflecting on the purpose of the material being studied and treat course material as unrelated sets of knowledge. The main study technique used by these students is to memorise facts and methods by rote and so they find it difficult to make sense of new concepts and ideas. As a consequence of this they will feel under pressure because of the amount of work involved in a course.

Deep learners

On the other hand students who exhibit a deep approach to learning will have a stronger interest in a course and seek to arrive at an understanding of the ideas and concepts forming the course. Typically, deep learners will relate new ideas to previous knowledge and experience by looking for patterns and underlying structures in the material being studied. While learning they will participate actively in the course and show an interest in the content and demonstrate the ability to relate new ideas and distinguish between evidence and argument.

Strategic learners

In addition a strategic approach to learning has been identified by several researchers, including Entwistle, (1998). These typically, are students who want to achieve a good grade in their course but are not really interested in the material or content. Students who are taking a strategic approach will make a consistent but focussed effort in their studies, but will be selective about the material they study. They are typically well organised, manage their time efficiently, and direct their learning towards the assessment requirements of a course. These students will often try to work in a way that they perceive to be what their teacher wants to see.

Although students may be classified as deep, surface or strategic learners this is not an attribute of an individual and cannot be said to be the result of certain character traits, for example, laziness. While some students will have a clear preference for one approach others may use differing approaches for different subjects depending on how they feel about a course or external pressures such as examinations or large amounts of work.

The approach that a student takes to their study affects their level of attainment. "*Research has shown that a deep, strategic approach to studying is related to high levels of attainment in higher education, while a surface approach is more likely to lead to failure*" (Entwistle 1998). Research has also shown that students who adopt a strictly strategic approach to their studies do nearly as well (in respect of the grades they achieve) as those who adopt a deep approach (Entwistle, 1998).

2.1.3 Conclusions

Learning theories provide a theoretical construct, which allows an understanding of a dialogue between a teacher and student and brings to the fore questions about a student's role in the learning process.

> *Constructivist psychology is valuable because it provides an account of how the individual learns through interaction with their world. This understanding then provides a principled approach to formal teaching, which can be designed to manage the interaction in such a way that it optimises the learning process.* (Laurillard, 2002).

In the context of this research, constructivism allows a qualitative assessment to be made of the discourse between a student and tutor and also provides a means to define the way in which students are expected to learn in the tutorials. The intention is that the students construct the mathematical ideas with the aid of the tutor. In order to achieve this goal it is important to have an understanding of this theory and the ways in which it differs from earlier models and theories of learning.

Laurillard (2002) argues that constructivism fails to offer a detailed link between "*teaching, student activity and interaction with the subject*". Laurillard (2002) further argues that findings from phenomenographic research offer the best way of generating a teaching strategy. Laurillard has developed a model in order to overcome this difficulty. She started with the constructivist learning theories and used a phenomenographic research method to develop her model. This model has been used extensively in this research project and is described in detail in section 3 of this chapter.

2.2 Desktop Video Conferencing (DVC)

2.2.0 Introduction

In order to carry out a literature search on DVC, it was first necessary to define the term precisely. This in itself was problematic since during the course of this research technological advances changed DVC significantly. Perhaps the biggest change being the introduction of broadband and network connections. This has had the effect of moving equipment manufacturers away from ISDN based systems to network connected systems and has resulted in the provision of better video images than were previously possible. Whilst this review does not consider the quality and diversity of systems available it considers those technical issues that may have an effect on the outcome of teaching and learning using this technology.

For the purposes of this literature review DVC is defined as a communications medium with the following properties:

i. It is computer based, and allows the user of one computer to connect to the user of another computer using any form of telegraphy that includes telephone lines, ISDN telephone lines and computer networks.

ii. It allows audio and video communication, synchronously, between the users of two computers. The users may be either individuals or small groups.

iii. It incorporates a whiteboard facility, which allows synchronous written working between two people.

iv. It allows files to be shared between two computers.

v. It allows both users in the conference to work collaboratively on a file. This means that both users are able to change, add to, or modify the file.

2.2.1 The unique aspects of DVC for one-to-tutorials

Perhaps because most research into the use of DVC has been in a one-to-many situation little reference has been made in the reports to some of the features of DVC that single it out as a unique teaching tool when used for one-to-one tutorials.

The interactivity enabled by the use of the whiteboard is very significant. When working in a one-to-one situation it is possible for both participants to work simultaneously on the same page with a full view of what each is doing at all times. Further the ability to share files and work collaboratively enhances a DVC session. Whilst it is possible to share files during any DVC session, for example enabling the contents of an essay in a Word file to be discussed, very little use seems to have been made of this facility. This may be due to a lack of technical expertise on the part of those using DVC and also the need for the computers being used to have large RAM capacity and fast processors. A lack of sufficient RAM or processor speed can lead to either the system 'crashing' or a loss of synchronous working between the participants.

DVC provides the ability to access many forms of resources; it is possible to use previously prepared files, standard software packages or web-based resources during a tutorial, which is thus not limited to a set text. The flexibility of the use of these resources is an important factor. Because DVC is situated within the environment of a computer the inherent ability to move quickly between windows can be used in DVC.

DVC allows instant feedback to students. Since it is possible for the tutor to see exactly what a student is writing on a whiteboard it is possible to provide feedback to the student when it is considered appropriate. This may be immediately after the student has made a mistake or when the tutor feels that prompting the student will help them to develop further the solution to a problem. Alternatively the tutor has the option to wait for the student to find his or her own error. The author's experience (based on working with over 400 students on a one-to-one basis) is that it often difficult to see exactly what a student is writing when paper is the medium. This is also the experience of the other tutor who participated in the study (see Chapter 4).

2.2.2 Reports on using DVC equipment

Numerous reports have been produced on how to make best use of video conferencing in general and DVC in particular. Two of the more authoritative reports are:

'*Support Action to Facilitate the use of Videoconferencing in Education*', research project (SAVIE, 1999). The European Community funded Telematics Application Programme that commissioned the project has produced a detailed report on how to make best use of the technology, including DVC. The report includes consideration of the choice of equipment, how it should be used and the planning necessary for its effective use.

'*Videoconferencing case studies*' published by The Institute for Computer Based Learning at Heriot-Watt University (ICBLa, 2002). This consists of eight papers, which detail how sessions using videoconferencing should be planned and conducted.

The recommendations of these reports were used to inform the positioning of the equipment at Exeter College and as a guide to the conduct and protocols for a DVC tutorial in order to make best use of the facilities offered by the system.

2.2.3 Reports on pedagogical issues of DVC

Little research has been done on the effectiveness of DVC as a medium for teaching. In fact, Laurillard (1993) went as far as to write, "*teleconferencing is essentially a solution to a logistical problem, rather than a pedagogical problem, normally used to overcome the problem of communicating with the students who are geographically distributed.*" This opinion is also shared by Dallet *et al* (1992). However in 2000 Laurillard wrote "*Videoconferencing is a one-to-many medium, making it a sensible way to provide access to a remote academic expert. The availability of video on the web enables DVC between individuals, though this is less likely to be used in education, except in special cases*".

This section contains a summary of reports published in the general area of videoconferencing and concludes with a section in which the common threads within them are identified.

Report 1- Whittaker (1995)

This early report on communication using telematics was drawn up from a large-scale analysis of research findings into the benefits of synchronous video to support communication between individuals. In the analysis there was an explicit assumption that the role of the video was to supplement the audio communication. Analysis of the key component of communication through face-to-face interaction concluded that it contained information on both 'content' and 'process'. To coordinate the content, mechanisms are required for the construction and maintenance of shared beliefs. In a discourse, utterances are said to radically under specify the speaker's beliefs and intentions. In practice this is not a problem as the listener makes inferences from the linguistic content and the physical context i.e. what they see from the speaker. Coordination of the process is the way that the conversation is managed. The key question was therefore whether poor or no video would preclude the conduct of well-structured discourse as defined earlier.

Non-verbal communication

Whittaker evaluated three different roles of non-verbal communication within a discourse, namely cognitive cueing, turn-taking and social and affective cues. Whittaker used comparisons between face-to-face, audio only and high quality video communication to draw the following conclusions under these three headings.

Cognitive cues are used to assess a participant's understanding through gestures such as nods of the head. For cognitive cueing audio-only was found to be as effective as face-to-face or high quality video. Removal of the audio had a dramatic effect on communication, even when video and whiteboard were present. It was concluded that the use of video must not be allowed to compromise the audio in any way. In contrast the addition or removal of video, text or writing media had little effect on task outcomes.

Whittaker claims that these results agree with other studies and therefore concluded that the video channel adds little to an audio only channel, when it comes to conversation content coordination between the speaker and listener.

Turn-taking cues lead to a smooth transition from one speaker to another during a conversation and may be indicated by movements of the head, eye movements and posture.

Whittaker found that there was little difference between audio and audio-video for pausing,, overlapping speech and interruptions. In practice it was noted that audio and audio-video systems did not replicate face-to-face conversational process. There was a reduced ability of speakers to take over the conversation spontaneously, and often formal techniques for handing the conversation to the other participant were used.

Whittaker concluded that the video channel added little to the management of the conversation compared with the use of audio-only. He thought that the reasons for this included the sound direction not identifying the actual speaker as it does in face-to-face conversations and that delays in transmission did not allow audio cues to trigger interactions in the normal way. Also the video channel did not provide sufficient information to show the facial expressions in conversation management and was subject to the same delays as the audio.

He does, however, note that the participants *"perceive"* turn-taking and response feedback to be improved through the use of social cueing.

Social and affective cues indicate a participant's emotional state and might suggest, for example a wish to terminate a conversation or change the subject. Facial expression, posture and eye gazing will typically give these types of cues (Whittaker, 1995). He found that participants focus more on the motives of others when they have access to visual information. Face-to-face and audio with video were found to be better media to use for tasks that rely on getting to know people. Video was found to benefit communication involving emotional factors and negotiation (i.e. bargaining, and conflict resolution) and these are less likely to end in deadlock. Social cueing was the only category where the addition of the video channel led to improvements over the audio-only channel.

Whittaker concluded that the audio quality is far more important than the video quality and that the former should not be compromised to provide the latter. This is significant with respect to DVC as one of the recognised weaknesses of the system is the quality of the video images. DVC does however provide good quality audio with virtually no time delays if used with ISDN or broadband connections. Whilst Whittaker has also concluded that the dialogue is not the same as with face-to-face it must be recognised (as discussed in the section on discourse analysis) that a conversation between a teacher and student is a very structured one which is conducted according to an implicit set of rules and is consequently very different in nature to the sort of impromptu conversation that might take place between two friends.

Report 2 - Reeves and Nass (1996)

This report evaluated the effect of various factors of the video quality on communication including image size, visual quality, audio quality and synchronisation.

Larger images were preferred and resulted in stronger memories and more positive responses to the content presented. Reeves and Nass questioned whether this is in fact a good thing, as the video image may actually detract from the learning process leaving the student with less mental energy "*to contemplate, rehearse or integrate information with prior experience*".

Reeves and Nass predicted and confirmed through experimentation that visual quality had no impact on the responses to a variety of tests. They put this down to humans being used to adapting to low levels of lighting which result in poor images. They concluded that there was no advantage to be gained through high quality video images.

Unlike video quality, poor audio quality was identified as being less natural and therefore likely to have an impact. Their results showed that attention, memory recall and subjective evaluation were all diminished by poor audio quality. They thought this was due to having to pay more attention to hear what was being said than interpreting the contents of the dialogue.

In a normal face-to-face conversation audio and visual inputs are exactly synchronised. The effect of the audio and video not being synchronised was difficult to predict. Reeves and Nass found that when the audio preceded the video, speakers giving presentations were rated lower, even when the participant had not consciously identified the difference. When communication is not synchronised it was found that conversations tended to become monologues.

On the basis that "*If the rule is that people will feel strong emotions when another person comes close to them, then people will feel strong emotions when a picture of a person comes close to them*". (Reeves and Nass, 1996). They also found that moving close to a camera added a sense of presence and forced the viewer into forming an opinion about the intrusion. Furthermore the viewer's memory of an image improved if the image was closer. On the negative side images of people focus attention towards primitive social cues, which may be to the detriment of other information being transmitted.

Report 3 - Bruce (1996)

A study by Bruce (1996) into the types of information that can be conveyed by providing a remote image of the speaker's face in a videophone concluded that a poor quality (even static) image was adequate for conveying the identity of the caller. A similar situation applied to emotions, however some small facial movements would be lost. Synchronisation of voice and image is necessary if the video image is to be helpful in interpreting unclear speech.

Report 4 - UCL (2002)

Research by the Language Department of University College London (UCL, 2002), noted that DVC offers the possibility of being used along side traditional face-to-face teaching, using the interactivity of the system. This interactivity allows a number of different computer based resources to be used virtually simultaneously; for example, questions can be cut and pasted from files on to the whiteboard whilst at the same using a web-based animation to explain a point. This interactivity is considered by the researchers in the Language Department of University College to have a pedagogical value.

A further example is that of students having access to the whiteboard, traditionally in the teacher's domain. Evaluators and observers of the ReLaTe (Remote Language Teaching) and PIPVIC (Piloting IP Videoconferencing) research projects expressed the view that the system showed potential for teaching the four main language skills of reading, writing, speaking and listening. The reason for this is because these four skills can be practised simultaneously through DVC, which is something that cannot be easily achieved in a conventional teaching environment.

Report 5 - Hearnshaw (1997)

Hearnshaw has carried out one of the most substantive research projects in the use of DVC in his doctoral research. This research used DVC to provide tutorial support to students in the ratio of one tutor to four students on an IT distance-learning course delivered by the University of Westminster. Participating students were located throughout the UK and each connected from their own computer to the tutor. The research specifically excluded a comparison with face-to-face tutorials, but rather focused on the quality of the audio and video and the possible impact of these on learning outcomes. A number of his conclusions are noted here.

He found that DVC could readily support dialogue in the circumstances in which it was being used. The type and quality of that dialogue however could only be determined by detailed analysis. However, Hearnshaw did note that Videoconferencing should primarily be used to support dialogue, and not for content delivery which does not require two-way communication.

In this study, the students' perceptions of DVC were quite variable. Some felt they would have participated more often in the tutorials if they had been face to-face, whilst others claimed that the DVC environment enabled them to be more focused and less prone to distractions. The fact that students were isolated appears to make tutorials feel more focussed with the high levels of concentration adding to the sense of intensity.

It was also found that poor image quality may in fact be beneficial as the lack of 'telepresence' may help to reduce the intensity of the tutorial and may reduce the mental effort directed towards interpreting the video image which is generally not subject specific. There is agreement between this research and that of others, (Kies, (1996), and Reeves and Nass (1996)), that video quality has no direct effect on learning outcomes.

There are pedagogical benefits in teaching over DVC and that "*rather than using videoconferencing to extend the customs and practices of the traditional classroom the possibilities and limitations of DVC must be clearly understood so that it can be used to maximise pedagogical benefits and minimise inherent limitations*".(Hearnshaw,1997). This is a view shared by Mayes (2002).

Hearnshaw suggests that there are basically two aspects to teaching, content delivery and content negotiation. In terms of this rote/negotiation distinction he believes that some subjects, for example those that are humanities-based, were negotiation-oriented whereas others, for example those that are science-based, were more rote-oriented. This distinction was important to Hearnshaw's research because it led him to conclude that DVC was poor for rote type content delivery and good for negotiation, whereas traditional lectures and computer-based instruction were good for content delivery and poor for negotiation.

This view of teaching is one that is not shared by this author and is clearly open to challenge, particularly in light of the phenomenological research detailed earlier in this section.

The implication of Hearnshaw's latter point is that DVC may be a good medium for learning within the Conversational Framework where a dialogue and negotiation can take place.

Report 6 - Midkiff (2002)

In a report on the SUCCEED project (Southern University and College Coalition for Engineering Education) being run in Virginia USA, Midkiff has identified DVC as a cost effective means to extend university teaching and mentoring to community college students, practicing professionals and other non-traditional students. Further it has allowed the sharing of resources between universities, especially for more specialised subject matter and also permitted access to unique remote resources such as high demand industry experts. As well as improving communication with more distant locations, DVC has enabled improved communications with traditional on-campus students. (Midkiff, 2002)

The report goes on to identify advantages of DVC that are not readily available with more expensive systems. DVC provides a more integrated environment with the computer, providing a *"richer set of supporting tools such as shared whiteboards and application sharing."* At the same time the report notes that DVC offers lower quality video than other systems but equivalent audio and often improved graphical communication. *"Studies have shown that the quality of audio and clarity of graphics are the most important factors for many distance learning applications"* (Midkiff, 2002).

One of the conclusions the report has drawn is that:

> *The instructional model must be carefully considered and a match must be made between instructional techniques and technology. DVC is particularly well suited for computer-integrated instruction where presentation graphics and software packages are used in the lecture. It is not well-suited for instruction where high quality video or rapid visual interaction is critical.* (Midkiff, 2002).

Report 7 - Ruthven and Hennessy (2002)

Ruthven and Hennessy conducted a study into the use of computers in school mathematics classrooms. They noted that the use of ICT changes the status of mistakes, not only by facilitating their correction, but also by removing evidence of them, which might attract unwelcome and demotivating attention from the teacher. The same comment would seem to be applicable to DVC where corrections to the work written on the whiteboard can be easily made.

Deeper and stronger student engagement in classroom activity, which improved behaviour, seemed to result from the use of computers. This resulted in better attention being paid to class work and a degree of independence and persistence in completing the computer based work. Further the use of technology, particularly for investigative type activities makes the classroom activity, especially amongst lower attaining pupils, more viable.

> *So while, in one sense, such use of technology was simply assisting teachers to realise an established form of practice, what is significant is that it is enabling them to employ this practice more effectively and extensively. At the same time, however, this and other ways of using technology, were giving rise to unanticipated phenomena, such as tinkering by students, which led to teachers having to reconsider aspects of their practice.* (Ruthven *et al*, 2002).

This, it is pointed out, is similar to Kerr's (1991) idea of 'cautious adoption' in which technology features in teachers 'thinking about their practice as a contributory, but subsidiary factor, which may lead to changes in teaching practices'.

Other Reports

The author is aware of three other small-scale projects where DVC has been used to provide tutorial support to students.

Report on Audio Conferencing - Newlands & McLean (1996)

This report details support provided to students on an HE Access course being run by the University of Aberdeen. The report sought to compare the learning experience of two groups of students: forty-five students were studying on campus and eighty were distance learners. Lectures were provided for the distance learners using audiotape, whilst those on campus received conventional lectures. One of the fundamental problems identified with traditional correspondence courses is the absence of face-to-face contact, which is seen as creating a number of difficulties. These include no heard language, the absence of non-verbal communication, the absence of feedback processes from the teacher to the student, delayed reinforcement, and the absence of student-to-student communication (Keegan, 1990). Tutorials for the distance learners were provided using audio conferencing between the University and a number of study centres and use was made of an electronic whiteboard.

The report stated that audio conferencing for tutorials was considered very different to face-to-face tutorials and should be treated as such. The staff found the one and a half hour sessions were mentally very tiring, not because of the length but rather because a greater proportion of the communication is borne by the senses of speech and hearing rather than sight. Newlands and Mclean also found that making frequent use of the whiteboard helped to hold students' attention.

Also identified in the report was the fact that the students were very tolerant of technical problems that arose. However the majority of the students did not find that the system was difficult to use. In fact, eighty nine percent of students questioned said they found the system easy or very easy to use.

Amongst the students studying on campus it was found that lectures, reading and essays were most valued as promoting learning and understanding with much less value being placed on the tutorials. Contrary to this the distance learners viewed the tutorials as the single most valuable aid to learning, reflecting the fact that the audio conferencing sessions were their only live teacher contact. This suggests that the distance students under went a different type of educational experience from campus students, but there is no indication that they viewed it as a second rate or inferior experience. Campus based students considered that student-to-student contact contributed very little to their learning, with only twelve percent considering it very important.

As withdrawal rates during the period of the study (1994/5) were very low, it was hypothesised that the use of audio conferencing allows the benefits of distance learning to be maintained whilst mitigating some negative aspects.

A number of benefits were identified in this study particularly that it was potentially cheaper for both the student and university. Further, it was possible to make available higher education opportunities, which would not otherwise be available, particularly for those who are geographically remote from a university. It was also considered that these distance courses promoted open learning, interpreted as being a student-centred approach.

The negative aspects identified by the project were: the absence of verbal feedback between student to teacher and teacher to student, delayed reinforcement, the absence of student-to-student communication and a lack of support networks to students resulting in feelings of isolation for the student.

Wright and Cordeaux (1996) and Jennings *et al* (1998) both used DVC to provide support to student teachers and have concluded that the best use of this technology (DVC) is in situations where communication is one-to-one.

Stripp (2002) reports that DVC has been found effective for providing support for up to four students on a higher 'A' level mathematics course.

2.2.4 Conclusions

Drawing together the common threads from these reports and the authors findings the following conclusions may be made.

The quality of the audio communication is vital to the outcome; clearly without this it is unlikely that a well-structured discourse could take place. Audio quality on DVC is generally good, particularly when using proprietary DVC packages. The quality of the video image is far less important and a good video image may in fact detract from the learning experience. Lack of synchronisation may be detrimental; this is seen as a diminishing problem as connections become faster.

There are a number of features to DVC that make it a unique teaching tool, such as the ability for a student and tutor to work simultaneously, and collaboratively on shared files. The way in which a tutor can give feedback either verbally or solely visually by e.g. using a highlighter, allows the feedback to either be given instantly or in a way which allows the student to find their own mistakes.

2.3 Literature review of the model used in the research

2.3.0 Introduction

This section looks at the Conversational Framework constructed by Laurillard (1993) that has been adopted as a model for this research. The way that this framework has been used in the research is detailed in Chapter 3.

The Conversational Framework developed by Laurillard is based on a one-to-one learning and teaching environment and was therefore an ideal structure to allow comparisons to be made between face-to-face and DVC tutorials all of which were conducted on a one-to-one basis. In her book "Rethinking University Education" Laurillard takes it as axiomatic that one-to-one tutorials are the ideal teaching situation. The difficulties of bringing a student to an understanding of a topic are recognised by Laurillard who states, "*Students have to be coaxed towards an awareness of what it is they fail to grasp. There is no room for mere telling, nor for practice without description, nor for experimentation without reflection, nor student action without feedback*"(Laurillard, 1993).

Others support the need for emphasis on dialogue. Lauzon, (1992) sees it as essential for a student to assimilate new ideas into their knowledge framework. The importance of dialogue as opposed to content delivery, which is not negotiated in the lecture situation, is also shared by Mayes *et al.*, (1994) who stated:

> *The medium of expression of that information is likely to be of only marginal importance, although the power of an effective representation must not be underestimated. This means that a primary exposition - an effective lecture, a powerful notation, an animated illustration, will serve to provide an initial contact with the conceptual knowledge that constitutes the subject matter. However, the (re) conceptualisation cycle will not occur without the operation of construction and/or dialogue. The interaction between the learner's prior understanding and primary exposition produces only an initial interpretation.*

Meaningful talk is seen by Catt and Eke, (1995) as the medium of intellectual development, and this is what most teachers would seek for their students, rather than an increased ability to absorb information. Support for the development of students' higher-order skills (that is, comprehension and application, analysis, synthesis and evaluation) has often been poorly facilitated (Mayes *et al.*, 1994), as it is a difficult area to address. Because of this, developments in educational technology have traditionally concentrated on improving the presentation of information, rather than making a more important contribution by improving the quality of instruction (Mayes *et al.* 1994).

To investigate how the process of learning and teaching can be most effective through dialogue in a one-to-one situation, Laurillard turned to the work of the phenomenographic researchers. Therefore this section starts by looking in general, at the relatively new form of research called phenomenography and then examines how Laurillard has used its findings to produce her framework.

2.3.1 Phenomenography

Phenomenography does not rely on theoretical constructs but rather on how students experience a learning situation and the understanding they derive from it. The focus then, is on the concepts (or misconceptions) that students acquire and not on learnt techniques.

The word phenomenography derives from phenomenology, which from a psychological perspective can be defined as the doctrine that psychology should focus on the contents of the mind, and that psychology's task is to explain the contents of the mind rather than to explain behaviour. From a philosophical perspective it is the doctrine of the 20th century philosopher Edmund Husserl who believed that philosophy must start from the scrutiny of one's own intellectual processes (Sutherland, 1995).

Marton, who first used the word phenomenography in 1981, has described phenomenography as the study of the variation in the ways people experience phenomena in their world (Marton, 1999) and as an empirical research tradition that was designed to answer questions about thinking and learning especially in the context of educational research (Marton, 1986).

Saljo, (1997), describes the aim of phenomenography as, *"clarifying functional relationships between what people do when they engage in learning activities and the nature of understanding they end up with".*

Marton, (1981), suggests there are two ways to approach the question of how learning occurs. The first is to orient us toward the world and make statements about it and its reality. The alternative is to orient us towards the ideas of other people and how they experience the world.

The essential difference between these two approaches is that we can either choose to study a given phenomenon or we can choose to study how people experience that phenomenon; phenomenography takes the second approach. In his original characterisation, Marton, (1981), distinguishes between what the scientific and the phenomenographic approaches would be, as exemplified by the following alternative questions:

i. Why do some children succeed better than others at school? (Scientific)
ii. What do people think about why some children succeed better than others in school? (Phenomenographic)

This leads not only to the need for the teacher to understand a topic but also to be aware of the conceptions and misconceptions that students bring to their learning. Saljo (1998), identifies these as "*a common sense conception of a phenomenon on the one hand and the conception used within the scientific-framework for understanding the very same phenomenon on the other hand.*"

In essence these ideas of conceptions are the same as Vygotsky's idea of everyday and scientific concepts. It is interesting to note that many everyday conceptions or misconceptions of scientific concepts mirror the historical development of ideas. "*Thus, for example, students have Aristotelian conceptions of motion*" (Laurillard, 1993). Piaget's experiments indicated that Aristotle's concept of motion is really that of the child. In other words, it represents the first approximation of a description of motion based largely on intuition. Aristotle lacked a clear definition of the terms used to describe motion. For example, he thought that freefall motion was acquired instantaneously and remained at a constant speed depending on what it was made out of and what it was falling through (Brill, 2004).

The empirical base for this type of research comes from discovery rather than applying hypothesis testing and uses qualitative rather than quantitative data. Marton, (1981,1994), believes that there is a limited number of qualitatively different ways in which various people will experience a phenomenon. Whether these conceptions are correct or incorrect by current standards is irrelevant from a theoretical standpoint as the objective is to elucidate the different possible conceptions that people have for a given phenomenon.

These differing experiences are characterised in terms of categories of description, logically related to each other, and forming hierarchies in relation to given criteria. Such an ordered set of categories of description is called the outcome space of the phenomenon in question.

Phenomenography goes further than just identifying different conceptions; it also looks for their meanings and the relationships between them (Entwistle, 1997). Marton (1981) describes a further aim of phenomenography as being:

> *Able to point not only to conceptions—making up its constituents—but also to relations between certain conceptions of one aspect of the world and certain conceptions of another aspect. What we have in mind is certainly not merely a listing of one conception after another. Some aspects are certainly more basic than others and different (and more or less fundamental) layers of the perceived world can be revealed.*

Marton (1994) also states that the different ways of experiencing a phenomenon are representative of the different abilities to deal with them, some of these ways being more productive than others. This allows the ways of experiencing and their corresponding categories to be arranged in a hierarchical order. The ordered and related set of categories is called the outcome space of the concept under study.

Phenomenography makes no assumptions about the nature of reality; consequently phenomenographers do not claim that the results represent the truth but rather that they are useful.

> *Phenomenography does not... have an articulate metaphysical foundation. The question may be raised if it has implicit metaphysical assumptions. Individual researchers doing phenomenographic research may make such assumptions but they certainly vary between the researchers. It is possible to have any and all of the metaphysical positions within the main categories of materialism and idealism and do phenomenographic research. The tradition is not based on any of these metaphysical beliefs and it is open in this respect.* (Svenson, 1997).

Whilst phenomenography makes no assumptions about reality, it does make assumptions about conceptions. The primary assumption is that concepts are a product of the interaction between an individual and their experiences of the world around them. In particular, conceptions arise from an individual thinking about their external world, and that these concepts are accessible in different forms but particularly through language (Svenson, 1997).

The main tool of phenomenographic research is open, deep interviewing. An alternative is to use open questionnaires. Interviews are open in the sense that there is not a rigid structure to them and deep in the sense that the interviewer will pursue a line of questioning until the interviewee has nothing new to say about a topic. The aim of the interview is to get the student to reflect on the experience under investigation and to communicate this to the interviewer in such a way that they understand the meaning of the experience from the student's perspective.

> *The experiences and understandings are jointly constituted by interviewer and interviewee. These experiences and understandings are neither there prior to the interview, ready to be "read off," nor are they only situational social constructions. They are aspects of the subject's awareness that change from being unreflected to being reflected.* (Marton, 1994).

Analysis of the data is carried out by identifying qualitatively distinct categories within which different people describe a concept. Phenomenographic researchers believe there are a limited number of categories for each concept and that these can be discovered by 'immersion in the data', which in most cases are transcripts of the interview (Booth, 1997). Transcripts are examined several times and the outcome space refined for each topic, the intent being to achieve consistency and determination of the outcome space with the minimum number of categories consistent with describing all the variations within the data. *"Definitions for categories are tested against the data, adjusted, retested, and adjusted again. There is, however, a decreasing rate of change, and eventually the whole system of meanings is stabilized"* (Marton, 1986).

Once a stable outcome space has been defined, the researcher attempts to develop "*...as deep an understanding as possible of what has been said, or rather, what has been meant*"(Marton, 1994). To do this, he needs to consider not only the specific categories of description, but also how the individual categories relate to each other and how one person's conceptions compare across different topics (Orgill, 2002).

The intended outcome from this type of the research is not to assign to any individual a particular concept of a topic but rather, by analysis of the group being studied, to build up a set of concepts that students may have of any particular topic.

The surprising outcome from this form of study is that what students know can be described in a relatively concise way provided the analysis is able to be carried out at the level of conceptions rather than procedures. Van Lehn and Brown (1980) for example, in their study of subtraction found eighty-nine procedural errors that students can make. In contrast to this Resnick and Omanson (1987) found just two ways that students mis-conceptualise subtraction. The implication for a teaching strategy is thus to resolve misconceptions as a prerequisite for remedying any procedural errors a student might make. Resnick and Omanson (1987) go on to conclude that:

> *If we look beyond the symbol manipulations of written arithmetic to what the symbols represent, the buggy algorithms (i.e. flawed procedures) look much less sensible.... It seems reasonable to suggest that a major reason that children invent buggy algorithms so freely is that they either do not know or fail to apply to calculation problems the basic principles relevant to the domain. If so, instruction focused on principles and on their application to calculation ought to eliminate or at least substantially decrease buggy-performance.*

One of the criticisms of this form of research is that there is a tendency to equate a student's experience to their account of it. Saljo (1997) comments that at times there appears to be a discrepancy between what researchers observe of a participant's experience of a particular phenomenon and how the student describes the experience. Richardson (1999) claims that phenomenographers do not critically assess the effect of interview techniques on the outcome.

Webb, (1997), levels the further criticism that the assumption that interviewers can act completely objectively while analysing data is not valid. In Webb's opinion they are more likely to hold certain theoretical beliefs that will influence their analysis and categorisation of data collected.

On the issue of reliability, Marton, (1986), says that it is possible that two different researchers would discover different categories of description while working on the same data individually. However, once the categories have been found, they must be described in such a way that all researchers can understand and use them. Marton compares this process to botanists that discover a new plant species on an island. If the new species does not appear to fit into an already existing category, the botanist must develop a new category of classification for it, and it is highly probable that a separate botanist would develop a qualitatively different category for that new species. However, once the botanist has developed and described a category, the category is accessible and available for classifying plants found by other botanists. Indeed, once the category is developed and described, it becomes useful to others who use the results of the study.

Despite these criticisms, Laurillard (1993) concludes that the methodology of phenomenographic research that seeks to identify fundamental misconceptions will yield far more of value than other approaches.

2.3.2 The Conversational Framework

Following analysis of a collection of phenomenographic studies Marton and Ramsden (1988) have proposed a number of teaching strategies. These are:

1) Present the learner with new ways of seeing.
2) Focus on a few critical issues and show how they relate.
3) Integrate substantive and syntactic structures. This focuses on integrating forms of representation with the event or system represented.

4) Make the learners' conceptions explicit to them.
5) Highlight the inconsistencies within and the consequences of learners' conceptions.
6) Create situations where learners centre attention on relevant aspects.
7) Test understanding of phenomena; use the results for diagnostic assessment and curriculum design.
8) Use reflective teaching strategies.

From the teaching strategies detailed above, Laurillard has constructed a Conversational Framework that provides a protocol for the way the academic dialogue should be conducted. The emphasis throughout is on the teacher reaching an understanding of the student's conceptions of a topic and modifying the student's conceptions where necessary.

To achieve this, Laurillard (2002) argues that the dialogue should be discursive, adaptive, interactive and reflective. They should be discursive in the sense that a teacher's and a student's conceptions should each be accessible to the other and the teacher and student must agree learning goals for the topic. Also the teacher must provide a discussion environment for the topic goal within which students can act, generate and receive feedback on descriptions appropriate to the topic goal.

An adaptive dialogue is one in which the teacher has a responsibility to use the relationship between their own conceptions and those of the student's to determine the focus of the continuing dialogue. An interactive dialogue requires the teacher to provide a task environment within which students can act on, generate and receive feedback on, actions appropriate to the task goal. Furthermore the students must act to achieve the task goal and the teacher must provide meaningful intrinsic feedback on their actions that relates to the nature of the task goal.

Reflective dialogue requires the teacher to support the process in which students link the feedback on their actions taken towards the topic goal for every level of description within the topic structure. The student must reflect on the task goal, their actions on it, and the feedback they received, and link this to their description of their conception of the topic goal (Laurillard, 2002).

Having established the characteristics necessary for a dialogue for learning to take place, Laurillard then goes on to establish the characteristics required of any medium to enable a meaningful dialogue to take place. These characteristics refer both to activities performed by the tutor and student and those that the medium must be capable of supporting in terms of communication between the tutor and student.

These characteristics can be divided between those required for the tutor and those for the student. The twelve characteristics established are summarised below. The number in brackets after each characteristic refers to its position in Figure 2.7.

Characteristics relevant to the tutor are that the tutor can:

i. Describe conception, (1).
ii. Re-describe the conception in the light of student's conception or action, (3).
iii. Adapt task goal in light of student's description or action, (5).
iv. Set task goals, (6).
v. Give feedback on actions, (8).
vi. Reflect on student's action to modify re-description, (12).

Characteristics expected of the student are that (s)he can:

i. Describe a conception, (2).
ii. Re-describe in light of tutor's re-description or student's action, (4).
iii. Act to achieve task goal, (7).
iv. Modify action in light of feedback on action, (9).
v. Adapt actions in light of tutor's description or student's re-description, (10).
vi. Reflect on interaction to modify re-description, (11).

The relationship between these characteristics, the medium, tutor and student is shown in Figure 2.7.

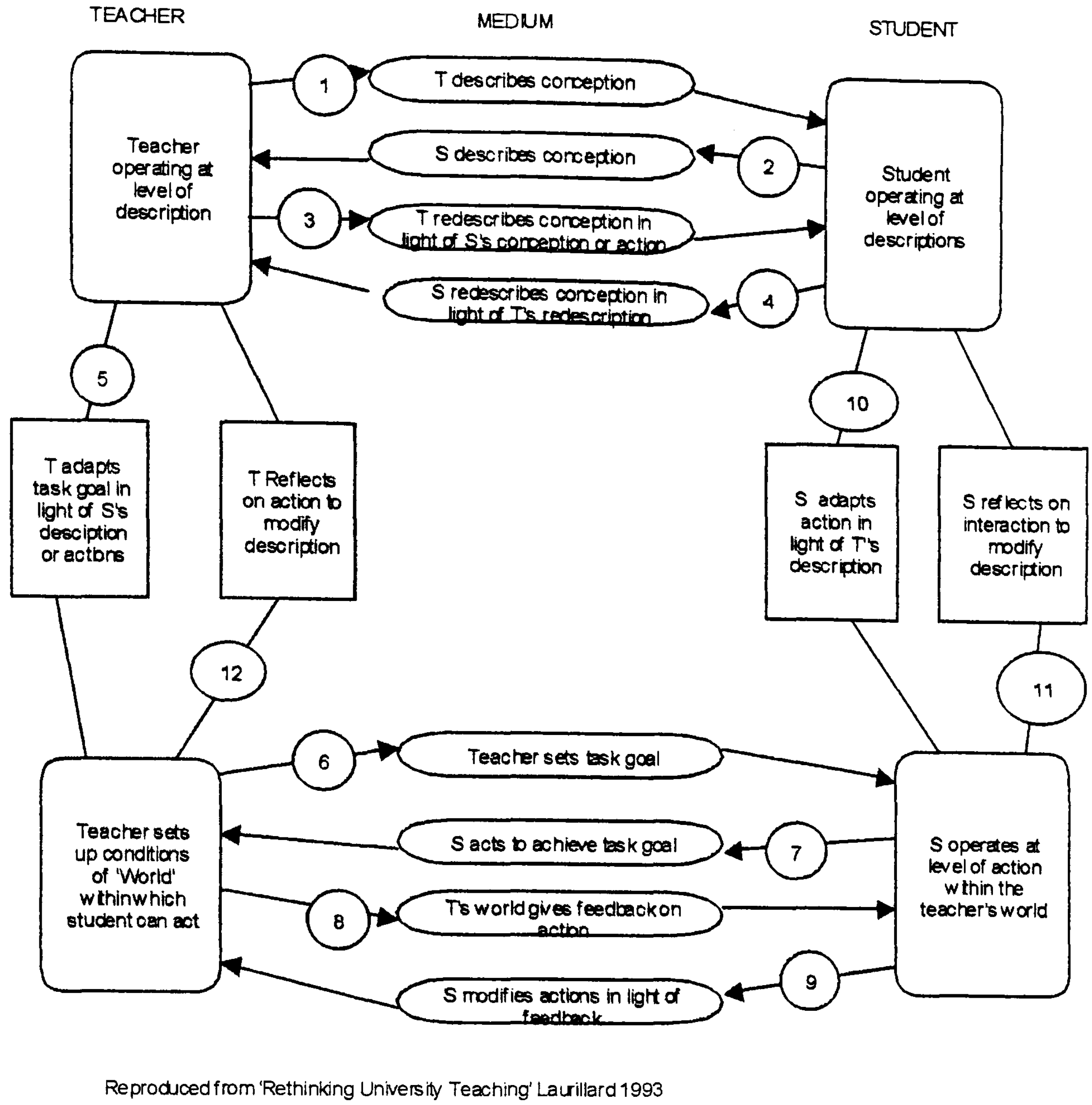


Figure 2.7: The Conversational Framework

Characteristics 5 and 10 (adaptation) and characteristics 11 and 12 (reflection) are activities that are internal to both the tutor and student and are therefore not able to be observed by a third party. The remaining characteristics are those which any medium needs to be capable of supporting and may be categorised as being interactive either at the level of description (1 - 4) or at the level of action (6-9).

The conversational framework then provides a set of characteristics or criteria against which any medium can be judged. Ideally, any medium that is used for distance teaching and learning should be capable of supporting characteristics 1-4 and 6-9.

None of the media evaluated by Laurillard was, in her judgement capable of doing this. The media considered by her were in five categories, which she defined as narrative, interactive, adaptive, communicative and productive.

Narrative media are the linear presentational media that include print (in the form of text and graphics), audio (usually audiocassettes), audio vision (an audiocassette talk accompanied by some separate visual material) and broadcast television of film and videocassette or digital disc. Interactive media are the presentational media that include a basic level of interactivity. These include hypertext, hypermedia, multimedia resources, web-based resources and Internet-delivered television. Adaptive media are computer-based media capable of changing their state in response to the user's actions. Communicative media are the media that serve the discursive level of the Conversational Framework and include telephone, email and videoconferencing. Productive media will entirely satisfy the demands of the Conversational Framework and covers media that allows the student to produce their own contributions via paper, disc, cassette or network (Laurillard, 2002). Table 2.1 shows which of the characteristics each type of media meet.

Laurillard's, (1993), classification of media did not include DVC. In Laurillard (2002) a brief reference is made to DVC, where it is included in a section covering videoconferencing and is classified as a communicative media.

Part of this research seeks to establish which of the characteristics of the Conversational Framework can be satisfied using DVC.

		Narrative	Interactive	Adaptive	Commun'tive	Prod'tive
1	Tutor can describe conception	√	O	O	O	O
2	Student can describe a conception.	O	O	O	√	O
3	Tutor can re-describe in the light of student's conception or action.	O	O	O	√	O
4	Student can re-describe in light of tutors re-description or student's action.	O	O	O	√	√
5	Tutor can adapt task goal in light of student's description or action.	O	O	√	O	O
6	Tutor can set task goal	O	O	√	O	O
7	Student can act to achieve task goal.	O	√	√	O	√
8	Tutor can set up world to give intrinsic feedback on actions.	O	√	√	O	√
9	Student can modify action in light of feedback on action	O	√	√	O	√
10	Student can adapt actions in light of tutor's description or student's re-description.	O	O	√	O	√
11	Student can reflect on interaction to modify re-description.	O	O	√	O	√
12	Tutor can reflect on student's action to modify re-description	O	O	√	O	O

Table 2.1: Media comparison by degree of fit to the Conversational Framework (Reproduced from Laurillard,D., (2002), Rethinking University Teaching

2.3.3 Other considerations

Whilst the research does not seek to assess the effectiveness of individual tutors, cognisance must however be made of the role of the tutor and the variations that occur in his or her performance. Recent extensive research amongst undergraduates has identified three key factors that govern a teacher's effectiveness (Patrick & Smart, 1998). These are, respect for students, the ability to challenge students and organisation and presentation skills.

Wood & Wood, (1996), have summarised effective interaction between tutor and learner in terms of providing a bridge, providing instruction in context and providing effective guidance.

Tutors serve to provide a bridge between a learner's existing knowledge and skills and the demands of the new task. Left alone the novice might not appreciate the relations between what a task demands and what they already know or can do that is relevant.

By providing instruction and help in the context of the learner's activity, tutors provide a structure to support the learner's problem solving. For example, while focused on their immediate actions, learners left alone might lose sight of the overall goal of the activity.

Although the learner is involved in what is initially, for them, 'out of reach' problem solving, guided participation ensures that they play an active role in learning and that they contribute to the successful solution to the problem. Effective guidance involves the transfer of the responsibility from the tutor to the learner. Not all guided participation involves deliberate or explicit attempts to teach and learn. Often interactions with the four characteristics just listed occur in everyday interactions between the tutor and learner where there is no specific learning agenda.

In designing Questionnaire 2 (see Chapter 3) to assess how effectively the characteristics of the Conversational Framework have been met, the above factors were taken into account and incorporated in to questions 6 and 7 of the Students' Questionnaire.

2.4 Discourse analysis

The author's interest in this area derived from seeking a tool that could be used for the analysis of tutorials to establish whether, particularly with DVC, the dialogue was well structured. By well structured it is meant that the dialogue follows the format of a face-to-face dialogue and hence the equipment is not placing limitations on the tutorial. Amongst researchers in this field (Stubbs, (1983), Sinclair *et al,* (1972), Coulthard *et al,* (1981)) there is agreement about the general nature and structure of discourse in a classroom situation, although there are considerable differences in the nomenclature used to describe the elements of a discourse.

Sutherland, (1995), defines discourse analysis as "*The study of how meaning is conveyed and extracted from spoken or written language ranging from a single sentence to a novel*", and continues that whilst progress has been made with single sentences, the complexity and variability of lengthier material has produced more "*noise than light*".

In the context of the classroom, the structure of discourse during the instructional phase of a lesson has been extensively researched (Coulthard & Montgomery, 1981). The structure is composed of a number of interactional sequences known as 'elicitation sequences' (Van Dijk, 1985), or 'exchange units' (Stubbs, 1983).

The form that a sequence takes is typically in three parts comprising an initiation act, a reply act and an evaluation act. The three-part sequence contains two coupled, adjacent pairs (Sacks *et al.*, 1974). Ervin-Trip, (1973), described the sequences as a concurrence relationship. A sequence is schematically represented in Figure 2.8.

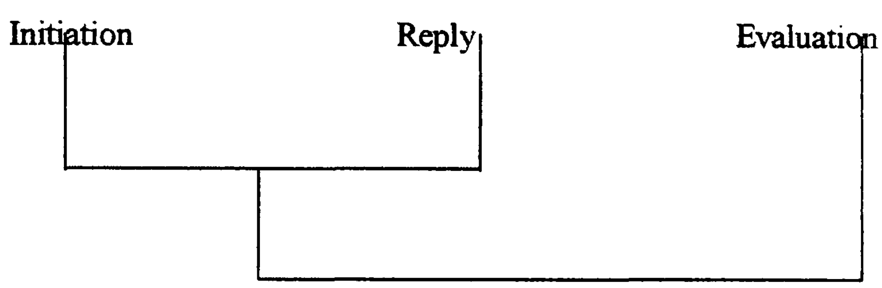


Figure 2.8: The concurrence relationship of an interactional sequence (Reproduced from Van Dijk, (1985), Handbook of Discourse Analysis.)

Initiation followed by reply is the first adjacent pair, which together with evaluation forms the second pair. The instructional phase of a lesson can be typically characterised as a progression of interactional sequences (Mehan, 1979).

Stubbs, (1983), develops this basic idea, from earlier work by Sinclair *et al.*, (1972), into the exchange unit. He views the exchange unit as being particularly suitable for the teaching situation where discourse operates within narrow parameters very much controlled by the teacher. The exchange unit is defined as the minimum discourse for a meaningful and structured dialogue to take place, (see Appendix 4 for definitions and notation used by Stubbs).

Structure of exchange units

The basic structure of an exchange unit is one in which an initiation **[I]** by the tutor is for example, followed obligatorily by a response **[R]** from the student and optionally by further interaction such as feedback **[F]**. If the exchange is defined as the minimal unit of interaction, then **[IR(F)]** is a primary structure for interactive discourse in general (Sinclair, 1980). A response **[R]** may be a non-verbal one if the teacher has directed the pupil to do something and **[F]** is optional. Other acceptable variations are:

a. Teacher-inform exchange **[Inf]** such as occurs during a lecture.

b. [I R/I R] (**R/I** being a response followed by an initiation by the same person).

c. When the teacher elicits a verbal response a three-element structure of the form **[I R F]** will occur with all three elements being obligatory.

Each of these may be followed by any number of **[Ir]** (re-initiate) and/or any number of **[F]'s**. The nature of the initiation **[I]** will determine the form of the exchange structure. If the teacher asks a question to which the student already knows the answer, it will lead to a different structure, in terms of the feedback, from that elicited by a genuine question.

Feedback is categorised as either obligatory or optional. This implies that the obligatory feedback must be predicted, not predicting, and not initial, that is, in a well-formed exchange unit it cannot form the first part and it does not require a following response. In the case of optional feedback it is not predicted, not predicting and not initial, that is, not required for a well-formed exchange unit, it cannot form the first part and it does not require a following response. Stubbs indicates an alternative approach to obligatory feedback by coding it as responses **[R]**, on the grounds that like responses they are predicted (Coulthard and Montgomery (eds), 1981). Where an exchange fails to follow an accepted sequence then it is considered to be an ill-formed string and is identified by * so for example ***[RF]** is ill formed.

This form of analysis of a dialogue uses the idea of continuous classification (Sinclair and Coulthard, 1975), in which each utterance is classified or interpreted in the light of the structural predictions set by the preceding utterance i.e. whether an utterance predicts a response or is in response to, a previous utterance and whether the utterance marks the boundary of an exchange.

Table 2.2 summarises the role of particular types of utterances and indicates those that are not acceptable. Hence for example if an initiation is terminal it is an ill-formed exchange unit.

	Predicting	Terminal	Predicted	Initial
I	√	(×)	×	√
R	×		√	×
R/I	√	(×)	√	×
F	×		×	×
Ir	√	(×)	×	×
Inf	×		×	√

Table 2.2: - Classification of types of statements

2.5 Conclusions

This chapter has reviewed the development of theories of learning, the use of computer technology in education and discourse analysis. This review has shaped the research in a number of ways.

The research work on video-conferencing has helped to determine the way that DVC will be used in the project. Some of the protocols for using the technology were arrived at as a result of ideas put forward by earlier research, although the additional features of DVC available at the time of the research provided additional tools and capabilities.

The review of learning theories helps to shape the evaluation of the project by providing insights into the different ways a student might learn. Laurillard tried to define, through her use of the Conversational Framework model the characteristics of a good, one to one tutorial and so, in this research these are considered alongside the knowledge gained from learning theories allowing a picture to build of the tutorial and whether successful teaching and learning is taking place.

Finally the review of discourse analysis has provided a valuable tool, which will be a key tool in the analysis of the tutorials. The fact that there are a number of notations has been noted and Stubb's methodology has been identified as the one that will be used for this research project.

Chapter 3 Research design and methodology

3.1 Research questions

3.1.1 Introduction

The primary aim of this research was to evaluate the effectiveness of tutorials delivered using the medium of DVC and compare this with traditional face-to-face tutorials. In line with the general strategy of including a number of different research approaches in the methodology the effectiveness of DVC was evaluated using the following data sources:

i. A statistical analysis of the mark obtained by a student re-sitting the mock examination for GCSE mathematics with as many relevant factors as possible being considered. It is readily acknowledged that it is beyond the scope of this research to measure some factors such as enhanced self-confidence and self-esteem. It is also recognised that these may have an effect on the outcome.

ii. Results from questionnaires administered throughout the life of a cohort.

iii. Interviews with some of the students receiving tutorial support using DVC.

iv. Discourse analysis of a number of tutorials, both face-to-face and DVC.

The secondary aim of the research was to evaluate, and quantify where possible, the effect that learning support had on the outcome; i.e. does learning support significantly improve performance in terms of examination results? This was investigated by comparing the results for those students who received learning support with a group of students who did not. Research by the Basic Skills Agency (1997), amongst others, has shown that the provision of learning support in Further Education Colleges increases the retention rate of students and that on average, the number of students successfully completing a course rises by just under 20%. The factors determining whether a student fails to complete a course are numerous and include among others, social (e.g. family situations) and academic (e.g. having little aptitude for a subject). This research sought to assess the effect of learning support on individual students in terms of their improved academic performance compared to their peer group who did not receive this type of support.

The research was not aimed at assessing the technology but rather how well the technology was able to provide an environment in which effective teaching and learning could take place. The ultimate aim must be for any new information technology to merge seamlessly into all fields of learning in much the same way as mathematics and the English language have already done. That is to say that the information technology becomes an accepted part of and a tool to aid learning in the same way as the electronic calculator has. The introduction of such technology may well in turn lead to other techniques becoming redundant; for example it may be that students will only use software packages such as Mathcad to draw graphs.

3.1.2 Hypotheses

The primary hypotheses postulated at the outset for the research were:

Hypothesis 1

H_0 *null hypothesis*: There is no significant difference in outcome between tutorials using DVC and those delivered face-to-face as measured by the mark achieved by Exeter College students in their mock examination prior to re-sitting GCSE mathematics.

H_1 *alternative hypothesis*: There is a significant difference in outcome between tutorials using DVC and those delivered face-to-face as measured by the mark achieved by Exeter College students in their mock examination prior to re-sitting GCSE mathematics.

Hypothesis 2

H_0 *null hypothesis*: One-to-one tutoring makes no significant difference to a student's performance compared to the students who just attended normal lectures as measured by the grade achieved in their mock examination prior to re-sitting GCSE mathematics.

H_1 *alternative hypothesis*: One-to-one tutoring improves a student's performance compared to the students who just attended normal lectures as measured by the grade achieved in their mock examination prior to re-sitting GCSE mathematics.

As other issues emerged during the course of the research, the scope of the research was broadened to investigate these issues using appropriate methods. For example, when it became clear that there were in fact differences between DVC and face-to-face tutorials, the use of discourse analysis was introduced into the research together with interviews of students in order to identify the nature of the differences between DVC and face-to-face tutorials.

3.1.3 Experimental design of the research

The experimental designs can be represented using the conventions of Campbell and Stanley (1963). The following diagram represents a quasi-experimental design.

Experimental	O_1	X	O_2
Control	O_3		O_4

Figure 3.1: Quasi-experimental design

In this diagram the following conventions have been used:

i. X represents the exposure of a group to an experimental variable or event, the effects of which are to be measured e.g. the number of learning support hours a student receives.

ii. O refers to the process of observation or measurement.

iii. Xs and Os in a given row are applied to the same persons.

iv. Left to right order indicates temporal sequence.

v. Xs and Os in the same column occur simultaneously.

vi. Adjacent rows separated by a dashed line represent groups not equated by random assignment.

In the context of the design to test Hypothesis 1, the specific representations are as follows:

X represents the exposure of the group to learning support delivered using DVC, the effect of which was to be measured.

O_1 and O_2 were applied to the group of all students receiving learning support for GCSE mathematics using DVC.

O_3 and O_4 were applied to the group of students receiving learning support for GCSE mathematics face-to-face.

In the context of Hypothesis 2, which took the same form, the aim was to compare students receiving learning support with the rest of the cohort for which the following specific conventions apply.

X represents the exposure of the group to learning support, the effects of which are to be measured.

O_1 and O_2 were applied to observations of the group of which all students were receiving learning support for GCSE mathematics.

O_3 and O_4 were applied to observations of the group of all students re-sitting GCSE mathematics at Exeter College.

All those students referred for learning support either by their tutor, lecturer or self-referral were asked if they would participate in the research. Those who declined to participate were allocated to a support tutor on the basis of their needs and the availability of the tutors. The students referred to the author for learning support were selected to either receive tuition face-to-face or DVC tuition on the following basis.

i. Year 1 (1998/1999) - The tutor's computer was located within the college and all students seeking learning support for mathematics were encouraged to use the DVC. During the year a number of technical difficulties were resolved. The most significant of these was a tendency for the software to 'crash' for no apparent reason. The system was found to be far more stable once updated versions of Netmeeting (2.1.1) and Proshare software (5.2) had been installed. The year was also used to develop protocols for the use of the DVC system and to test questionnaires.

ii. Year 2 (1999/2000) - The tutor's computer was located some 5 km from the college. Whether or not the student received support using DVC was largely determined by the availability of the student and other teaching commitments of the author. During the second year (unlike the first) the author was not responsible for allocating students seeking learning support to tutors. The effect of this was that the type of support that a student received was to some extent randomised. All students allocated to the author were actively encouraged to have their support using DVC, with the option to receive the support face-to-face if they preferred. Timetabling constraints on the author meant some students had to receive their support face-to-face.

iii. Year 3 (2000/2001) - During the third year of the research, all support given by the author was by DVC as the database required for the comparison group in experimental design 2 was insufficiently large. At the same time, data continued to be collected from tutorials conducted face-to-face by other tutors.

Table 3.1 shows the number of students in each of the experimental design groups over the three-year period of data collection.

Academic year	Year number	No of students Starting course	No of students sitting GCSE	No of Students Receiving Support for GCSE mathematics
1998/1999	1	310	120	7
1999/2000	2	297	82	8
2000/2001	3	261	73	13

Table 3.1: Students in GCSE cohorts and the number of students receiving support

The extent of the support received by students and the form that the support took varied considerably with some students receiving both face-to-face and DVC tutorials.

3.1.4 Validity of the experimental design

Validity can be defined in psychological terms to mean " *The extent to which a test or experiment genuinely measures what it purports to measure*" (Sutherland, 1995).

Campbell & Stanley (1963) and Bracht & Glass (1968) have identified conditions that might jeopardise the validity of experiments. These conditions will tend to have a more 'clouding' effect on experiments in the social sciences rather than in true scientific experiments. This is because in a true experiment the researcher is more able to randomly assign the treatments and the researcher can better control both the treatment and measurement. In the context of this study treatment would be learning support.

These conditions may be divided into two categories, internal and external, which are now considered in more detail.

Internal validity

Internal validity is concerned with the question, "*do the experimental treatments, in fact, make a difference in the experiment under consideration?*" Cohen & Manion, (1994). It is necessary to show that the data accurately supports the explanation of a particular event. This implies that if this condition were satisfied, then the data itself would be capable of replication by another researcher and have the same outcome.

Cohen and Manion (1994) have summarised the threats to internal validity identified by Campbell & Stanley and Bracht & Glass as follows:

1. **History** - In educational research, factors other than those being considered may occur that contribute to the effect being measured. That is, these factors may have an effect that cannot be identified or recognised. For example, some of the students in the study will have been receiving (one-to-one) tuition from members of their peer group or from private tutors, which would impact on their GCSE performance.

The treatment of the experimental group and the control group within the framework of teaching provided by Exeter College varied only in the treatment under investigation, the only difference being that the experimental group received learning support in one of two ways, either face-to-face or using DVC.

2. **Maturation** - In the duration of a study, subjects may change in a number of ways. These changes may be caused by factors that are independent of the study. A student may, for example, improve their problem solving skills through studying another subject, or their attitude and motivation may improve on realisation that their university of choice will not accept them without a better grade in GCSE mathematics. The longer the period of study of a particular cohort the greater the impact of these influences can be. In this study, each cohort was effectively studied for one academic year. Whilst maturation may have had some effect, the period is relatively short in terms of educational research and so it was not considered likely to have had any significant effect on the outcomes.

3. **Statistical regression or regression to the mean** - This effect increases with the time interval between tests and occurs in educational research due to the unreliability of tools used for measuring the effects of a particular treatment and to extraneous factors unique to each experimental group. Regression means that subjects scoring highest on the first test are likely to score relatively lower on a post-test; conversely, those scoring lowest on a pre-test are likely to score relatively higher on a post-test. The effect of this is that all members of the cohort tend to move towards the mean score

for the cohorts. In this research, since the experimental group and the control group were all part of the same cohort there were not likely to be any extraneous effects that affected one group alone.

4. Testing - Tests carried out at the beginning of a research project can produce effects other than those due to the experimental treatments. Such effects can include producing higher scores on post-test measures due to practice or simply exposure to the topics.

Tests used in this research were common to both the experimental and control groups and were not repeated. It is therefore reasonable to assume that the impact on both groups would be the same and that the impact on the students' score in their mock examination would be minimal as the tests was different to the actual GCSE papers. The pre-test comprised an initial assessment test (see Appendix 6 for details) and the post-test was the preliminary examination, which was one of the previous years GCSE examination papers.

5. Instrumentation - Where data collection relies on human observation, error can result from changes in the observer's skills and levels of concentration over the course of the experiment. The tools used may also be unreliable producing serious errors, such as would occur with a flawed IQ test.

The pre-test in this research was based on a shortened version of the tests for the Mathematics Enhancement Programme, developed by the Centre for Innovation in Mathematics Teaching (CIMT) at the University of Exeter, for which the reliability and validity have been established (Burghes, 2000). The results from the post-tests were the preliminary examination results. Over the period of data collection three previous GCSE papers were used for the preliminary examination and it is acknowledged that there may have been variations in the difficulty of the papers. With the relatively small number of students taking the examination each year at Exeter College, moderation of the results was not deemed practical.

6. Selection - The process of selecting a sample from a group may introduce bias. The effect of this may be further increased when combined with other factors (history, maturation etc). Those participating in the experiment were self-selecting. That is, out of the whole cohort of students re-sitting GCSE mathematics they were the students who had been referred, either by themselves or a member of staff, for learning support. The decision to seek learning support had been made independently of the researcher. This group formed a sub-set of the whole cohort and cannot be described as a random sample. None the less, it is specifically because they have opted to seek help with their studies that they form a random sample with a common factor.

The author's observations (over a period of 12 years) of students seeking learning support is that they are on average well motivated, particularly if they have sought the help themselves, rather than as sometimes happens, being pushed into receiving support by their tutors.

7. **Experimental mortality** - The effect of subjects dropping out from a long running experiment may result in confounding the effects of the experimental variables. If initially the groups had been randomly selected, the residue that stayed the course were likely to be different from the unbiased sample that began it.

Mortality amongst the experimental group was very low, whilst that amongst the whole cohort was high (around 85%). This difference is considered to be due to two factors:

i. The students seeking learning support are generally better motivated.

ii. The tutoring they received, in addition to improving their mathematics, also improved their confidence and self esteem.

The mortality rate remained much the same from year to year during the course of the research and only those completing the course and sitting the examination were included in the statistical analysis. Whilst those completing the course formed a small sub-set of the original cohort there is no reason to suggest that there was then any marked difference between those receiving support and those not.

External validity

External validity considers the following question: given that the treatments do cause the effects, to whom and in what situations can the results be generalised?

In this research the treatment received by the students at Exeter College must be viewed as unique to that institution. However, as the group under study formed a sub-set of the whole group the value added effect, if any, of learning support should be generalisable to any similar group of students.

Additionally, as there is no apparent difference between the students at Exeter College and any other FE college, the findings in respect of the use of DVC should be applicable to all such students at any similar college. Thus, for example, if DVC is more effective than face-to-face tutorials and the reasons for this are not unique to Exeter College, it would seem reasonable to assume that the result would apply to any similar college.

Threats to external validity can limit the degree to which generalisations can be made from the particular experimental conditions to other populations or settings. Cohen and Manion (1994) have summarised the threats to external validity identified by Campbell & Stanley (1963) and Bracht & Glass (1968) as follows:

1. **Failure to describe independent variables explicitly.** Unless these variables are adequately described then another researcher, independently of the first, cannot replicate the work. Included in the appendices to this thesis are examples of all documentation used in the research to measure each of the variables considered.

2. **Lack of representativeness of available and target populations.** This addresses the issue that whilst those included in the research may be representative of the population under study they may not be representative of the population to which it is hoped to generalise the results.

Exeter College is the only FE College in the immediate vicinity of Exeter. Furthermore, Exeter has no grammar schools and thus the vast majority of students who receive their secondary education in Exeter go on to the college for their further education. A small proportion transfer from the state sector to private education and vice-versa, a situation that must apply to most FE colleges. This situation is not typical of other towns and cities in the region where in many the students stay on at school to study for their 'A' Levels. It must therefore be recognised that results achieved in respect of academic attainment will probably not be generalisable.

Within the college the entire population of students re-sitting GCSE mathematics was included. Those seeking learning support were selected independently of the researcher, being either by self-referral or on the advice of their tutor or lecturer. Those students receiving support were not representative of the population from which they were drawn; rather they were those students who had identified a need for additional help in order to succeed. This might have been for any of a large variety of reasons such as dyslexia, a general weakness in the subject, high motivation or the need to succeed in order for example to go on to university. These reasons would equally well apply at any other FE college.

3. **Hawthorne effect.** This is described by Sutherland, (1995) as:

> *The phenomenon that if an attempt is made to improve workers' performance by introducing new methods, productivity tends to increase regardless of the value of the new methods; the workers may become more enthusiastic because they are receiving more attention or because they feel the management is trying. This phenomenon makes it hard to test the value of an innovation.*

This effect has historically been recognised in medical research for a long time and the psychological effects that arise out of mere participation in drug trials are well recognised. In medical research there may be an effect induced simply by participation in the tests and to mitigate these effects placebos and double blind designs are widely employed. Similar effects threaten to contaminate experimental treatments in educational research when subjects realise their role as guinea pigs.

The effect can be viewed as modifying the behaviour of the subjects participating. In the context of this study this may mean a possible improvement in the performance of the tutor and greater commitment on the part of the student to their studies.

Research by Jennings *et al.*, (1997), indicated that the use of DVC leads to more planned and focussed tutorial sessions. The planning took the form of better preparation of teaching materials by the student which they wished to discuss with the tutor, which led Jennings to conclude that the students were more focussed. This is viewed as a positive benefit of using the technology. Whether this benefit derives from the Hawthorne effect or is a consequence of using DVC is one of conjecture since, as with medical research, it is not possible to separate the psychological effect of being included in the research from the effects of the research. However if this is a valid, sustainable effect of using DVC, then it can be considered a parameter of the research. The author did not become aware of any diminishing student interest in using the technology; on the contrary, for many it was viewed as acquiring another IT skill, and thus was a bonus of the process.

4. Inadequate operationalising of dependent variables. The dependent variables that the experimenter uses must be valid in the non-experimental setting into which the findings are to be generalised. That is to say that the variables introduced in the experiment, in this case tutorial support either face-to-face or using DVC, must be equally applicable to the non-experimental situation if the results are to have more general validity.

The tutorials conducted at Exeter College were similar in style and content to those found in any other college and so could be easily replicated by any other college. Included later are recommendations for the conduct of DVC tutorials based on the experiences gained whilst carrying out the research.

5. Sensitising to experimental condition. As with threats to internal validity, pre-tests may cause changes in the subjects' receptiveness to the experimental variables. This is not seen as being applicable to this research as only one test was conducted which was done in advance of students receiving learning support.

Whilst internal validity does not imply external validity, it is never the less a prerequisite. It therefore follows that in an experimental situation both the internal and external validity must be maximised.

3.2 Research methodology

3.2.1 Introduction

Within the field of social science there are two differing views of how human behaviour can be explained. There are those who believe that all human behaviour can be explained in terms of rules (positivism) and others who believe that positivism excludes such issues as moral responsibility, choice, motivation and other personal individualistic characteristics.

Underlying the design of this research methodology is the idea of triangulation of methods (discussed later); this means that a number of different methods, based on possibly differing epistemologies, are used. Thus it is hoped that the outcome from one method will provide corroborative evidence for the findings of the others.

This approach was considered desirable since much of the research in the field of social science, which is based purely on 'scientific methods', produces outcomes that are inconclusive and unlike research in the natural sciences the opportunity to repeat experiments within a reasonable time frame may not occur.

The primary aim of the research was to compare the effectiveness of DVC with the traditional face-to-face tutorial and thus the use of empirical techniques was considered particularly appropriate. As Cohen and Manion (1994) stated, *"since educational theory is only at its early stages of formulation it must be dominated by empirical work, that is, the accumulation and classification of data"*.

In parallel to the use of empirical techniques a number of qualitative approaches were used including open questionnaires and interviews. These were considered important in order to provide insight into how students perceived the tutorials. This approach can be broadly described as phenomenographic.

3.2.2 Positivistic paradigm

A positivistic paradigm is grounded in the scientific method and accepts natural science as the paradigm of human knowledge. Positivism is associated with the 19th century French philosopher, Auguste Comte and refers to the application of the scientific method to social science.

Hitchcock and Hughes (1995) have summarised the scientific method as having eight stages; these are:

i. Hypotheses, hunches and guesses.
ii. Experiment designed, samples taken, variables isolated.
iii. Correlations observed, patterns identified.
iv. Hypotheses formed to explain regularities.
v. Explanations and predictions tested, faithfully.
vi. Laws developed or disconfirmations (hypothesis rejected).
vii. Generalisations made.
viii. New theories.

In applying these stages to educational research certain assumptions have to be made:

1. That social phenomenon must have an ontological reality, which is that they must exist independently of the individual.
2. An assumption of an epistemological nature, which assumes that knowledge, can be transmitted and thus acquired.
3. That human behaviour is essentially governed by rules.

This approach allowed the use of data collection and analytical techniques to investigate the relationship between selected factors. Thus the research was descriptive, defined by Best, (1970) as concerned with how "*what is or what exists*" is related to some preceding event that has influenced or affected a present condition or event.

The generic term conventionally used to describe the perspective represented by the positivistic approach is 'normative'. Thus, the data collection and analysis part of the research may be said to have been situated within a normative paradigm. That is, human behaviour is essentially governed by rules, and human behaviour should be investigated by the methods of natural science (Cohen & Manion, 1994).

3.2.3 Anti-positivistic paradigms

As differences emerged between the two modes of delivering tutorials anti-positivist approaches were adopted in an attempt to identify the nature of the differences. Subjective reflection by the author and discussions with students became necessary tools to identify the more intangible nuances of a tutorial.

Whilst a number of alternative approaches to anti-positivism exist, Cohen, Manion and Morrison (2000) have identified the following distinguishing features of anti-positivism:

i. People are deliberate and creative in their actions; they act intentionally and make meanings in and through their activities (Blumer, 1969).
ii. People actively construct their social world – they are not the 'cultural dopes' or 'passive dolls' of positivism. (Becker, 1970:Garfinkel, 1967).

iii. Situations are fluid and changing rather than fixed and static; events and behaviour evolve over time and are richly affected by context – they are 'situated activities'.

iv. Events and individuals are unique and largely non-generalisable.

v. The social world should be studied in its natural state, without the intervention of, or manipulation by, the researcher (first postulated by Hammersley and Atkinson, 1983).

vi. Fidelity to the phenomena being studied is fundamental.

vii. People interpret events, contexts and situations and act on the basis of those events.

viii. There are multiple interpretations of, and perspectives on, single events and situations.

ix. Reality is multi-layered and complex.

x. Many events are not reducible to simplistic interpretation; hence 'thick descriptions' (Geertz 1973) are essential rather than reductionism.

xi. We need to examine situations through the eyes of participants rather than the researcher.

The interpretative paradigm, as it is called, seeks to make understanding of an individual's interpretation of an event. *"Theory is emergent and must arise from particular situations; it should be 'grounded' on data generated by the research act"* (Glaser and Strauss, 1967). The theory then becomes the meaning that gives insight into behaviour. These meanings will not be universal but unique to an individual.

In the context of this research an anti-positivistic approach has been used to determine what a student thought of DVC, where they thought the advantages and disadvantages of the system laid and their reaction to DVC. Was it to them an enjoyable experience, and if not, why not? The reasons given will be particular to that individual although they may be common to a number of other students. The experience of using DVC will be one that is unique to every student, however if common themes emerge it is not unreasonable to assume that other students would experience DVC in the same way.

3.2.4 Longitudinal study

The research took the form of a longitudinal study of the cohort analysis type, defined by Cohen & Manion (1994), as a study in which information is collected on one or many individuals over a time span long enough to encompass a detectable change in developmental status.

In the context of this research a cohort consisted of all students studying GCSE mathematics in a particular academic year and longitudinal study refers to the period of time for which they studied for their re-sit.

This research covered four consecutive cohorts who received tutoring, of which empirical data were collected for three of them using a cluster sample (the entire population of students at Exeter College re-sitting GCSE mathematics). Each cohort covered one academic year.

Exeter College offered a unique research opportunity in the Southwest of England in that it had the largest population of students studying to re-sit GCSE mathematics, it being the only tertiary college serving Exeter and its environs, with approximately four hundred students each year enrolling for GCSE mathematics re-sits and all being subjected to the same learning experience. Students studied in 'workshops' using modular booklets developed by the college and supported by tutors.

A longitudinal study of a number of cohorts was considered the most appropriate approach as the research sought amongst other things to find a causal relationship between the outcomes achieved by a student and the learning support, they had received. It also allowed the students' attitude to DVC to be monitored over a period during which the students gained experience in its use.

> *Cohort studies of human growth and development conducted on representative samples of populations are uniquely able to identify typical patterns of development and to reveal factors operating on those samples which elude other research designs...Cohort studies too, are particularly appropriate when investigators attempt to establish causal relationships, for this task involves identifying changes in certain characteristics that result in changes in others.*
> (Cohen & Manion, 1994)

Douglas's (1976) analysis of the advantages of cohort analysis type studies, as compared with cross-sectional designs (i.e. ones that produce a 'snapshot' of a population at a particular point in time), which are applicable to this research, can be summarised as follows:

i. Some information such as the initial assessment test is only meaningful if collected contemporaneously. Other types of information are more complete if collected during the course of a longitudinal study, thus for example collecting details of a student's previous education can be collected and checked at any time whilst the student is still a member of the cohort. This has the advantage that if a student is initially missed there is still the opportunity to collect the data at a later stage, thus increasing the size of the database.

ii. Cohort studies avoid duplication of the collection of information, so where students spent more than one academic year on their GCSE mathematics re-sit, data and details of the student could be carried forward as they became a part of the succeeding cohort.

iii. The omission of a single variable, which subsequently proves to be important, can usually be overcome by further data collection or interview. In this research, new variables such as the initial assessment test were added after the first cohort had completed their studies. The effect of this was that the data collected during the first year could not be included in the regression analysis.

iv. Cohort studies allow the accumulation of data on a much larger number of variables at appropriate times during the study than would be possible with a cross-sectional study.

v. Longitudinal studies are free of one of the major obstacles to causal analysis, namely the re-interpretation of remembered information and provide the means to assess the direction of effect. In the case of this research it meant that an initial impression of DVC could be captured at the time of the first session and compared with the results of the final questionnaire completed after the students had finished their course. In other words, the students were not being asked to remember their first impressions of DVC some time after the event, instead these were recorded at that time.

The recognised disadvantages of a longitudinal cohort study are:

i. Longitudinal studies generally fail to address genetic changes that occur in the sample population during the course of the study. The developmental rate of students over time will vary and students will reach any given growth stage at different ages. Most studies, including this one, ignore chronological age; therefore it is argued (Wall & Williams 1970) that every study must be short and limited to a clearly defined segment of growth. The cohorts under study in this research covered a period of nine months from entry into the college to re-sitting their GCSE mathematics examination.

ii. Sample mortality, that is, subjects dropping out from the experiment, is likely. The degree to which this happens and the impact it has on the research cannot be foreseen. In the case of this research a very high mortality rate was expected from the outset as records from previous cohorts at the college showed a dropout rate of around 85% amongst the population re-sitting GCSE mathematics. This meant that much of the data collected during the early life of a particular cohort could not be used in the statistical analysis, as the students had not progressed to the point of sitting their mock GCSE examination. To overcome this, data were collected over two cohorts to establish a minimal acceptable database. Whilst there is no definitive size, the minimum size of thirty (Cohen & Manion, 1994), was rejected for the purposes of multiple regression analysis and a criteria of a minimum size of sixty was set as a target. This sample size was chosen because of the large number of variates being included in the analysis.

iii. The control effect (or measurement effect) may influence the actions or attitudes of the subjects being studied. The students in this study found themselves subjected to many questionnaires and data collection exercises by their own peers, this being an element of the GNVQ courses followed by many of the students.

To avoid as far as possible the questionnaires being viewed by the students as a further meaningless exercise the purpose and background to each questionnaire was explained briefly to them and the questionnaires were generally kept short and used relatively infrequently.

iv. Randomising of students receiving tutorial support was not possible, as allocation of students from the main population was on the basis of student choice. There is therefore an implication that those students seeking learning support will be better motivated than if the students had been randomly allocated to participate. Some randomising of the type of support that students received was possible during the last two years. This was achieved by students being allocated to a tutor on the basis of the availability of the tutors and not the type of tutorial support being offered.

v. Zarro, (1967), in an address to a symposium on longitudinal studies criticised longitudinal research as being rigid in theory and instrumentation and thus lacking the essential freedom necessary in the search for the unknown. Wall & Williams, (1970), expressed a contrary view, "*It is just this lack of rigidity that is often levelled against it, with the emergence of new hypotheses during the period of the research*".

The author believes that retaining an open mind about further avenues for research is essential if the most is to be achieved from the research. Thus the original hypotheses may well be modified or replaced, resulting in the direction and emphasis of the research changing as a consequence of early results and reflection. This may also have the result that the research questions are expanded to look at the effects and their causes, of factors or parameters not previously recognised.

After three years of this research when it became apparent (but not proved) that DVC was at least as good as, if not better than, face-to-face tutorials, the focus of the research changed to looking at the essential differences between the two forms of tutorial, in an attempt to identify the differences between them. To help in the process of identifying these differences, discourse analysis was applied to recordings of tutorials (discussed in section 3.3.4).

vi. Demand characteristics, defined as "*The features of an experiment that, without the experimenter realising it, may prompt the subject to behave in a particular way*" (Sutherland, 1995), may occur due to the expectations of the researcher. Questionnaires were clearly prone to this effect and so in an attempt to negate the effect, questionnaires included questions on what the student saw as the negative aspects of DVC. For example, the initial questionnaire asked students to list those things they did not like about DVC. Some of the students completed the final extended questionnaires anonymously.

"Nevertheless, however great the methodological difficulties, the longitudinal approach is essential if we wish to determine the influence of conditions, acting over a period of time, on the same individuals" (Wall & Williams 1970).

Since the research aimed to study the use of DVC with students over a period of time a longitudinal study was the obvious choice for the research.

3.2.5 Triangulation

Triangulation i.e. "*the use of two or more methods of data collection*" (Cohen & Manion, 1994), was adopted as this facilitates the utilisation of both quantitative and qualitative methods. This approach has two main advantages.

Firstly, whereas an experiment, for example in the field of physics, may well produce unambiguous findings about the phenomena being investigated, this is unlikely to be true when applied to the complexity of human behaviour. Smith, (1975), observes "*that as research methods act as filters through which the environment is selectively experienced, they are never atheoretical or neutral in representing the world of experience*" and Lin, (1976), further cautions that "*exclusive reliance on one method, therefore may bias or distort the researcher's picture of the particular slice of reality she is investigating. She needs to be confident that the data generated are not simply artefacts of one specific method of data collection*".

The second advantage is that it avoids method-boundness, a tendency by researchers to rely on just one approach either because those methods are the only ones they are familiar with or because they believe them to be superior. This problem was identified as early as 1953 by Boring who wrote:

> *as long as a new construct has only the single operational definition that it received at birth, it is just a construct. When it gets two alternative operational definitions, it is beginning to be validated. When the defining operations, because of proven correlations, are many, then it becomes verified.*

Triangulation has been further categorised by Denzin, (1970), whose typology of triangulation methods, is summarised in Table 3.2.

1. *Time triangulation*: Attempts to take into consideration the factors of change and process by utilising cross-sectional and longitudinal designs.
2. *Space triangulation*: Attempts to overcome the parochialism of studies conducted in the same country or within the same subculture by making use of cross-sectional techniques.
3. *Combined levels of triangulation*: Uses more than one level of analysis from the three principal levels used in the social sciences, namely, the individual level, the interactive level (groups), and the level of collectivities (organisational, cultural or social).
4. *Theoretical triangulation*: Draws upon alternative or competing theories in preference to utilising one viewpoint only.
5. *Investigator triangulation*: Engages more than one observer.
6. *Methodological triangulation*: Uses either a) the same method on different occasions or b) different methods on the same object of study.

Table 3.2: Principal types of triangulation, reproduced from Cohen & Manion (1994)

Triangulation methods used in the research were:

Methodological triangulation

Table 3.2 above identifies two types of methodological triangulation; both were used in the research.

i. Type a). The same research tools and methods were applied to three consecutive cohorts.

ii. Type b). Different methods were used within each of the cohorts, i.e. the principle of triangulation was applied to the study of each cohort, with the use of different research tools and methods, which can be categorised as both positivistic and anti-positivistic.

The methods used were:

i. Statistical analysis of the quantitative data.

ii. Questionnaires.

iii. Interviews/extended questionnaires, given to students on completion of their course.

iv. Discourse analysis applied to a number of transcripts and later recordings of tutorials.

Time triangulation

Time triangulation was applied in the sense that:

i. The same techniques were applied to two of the cohorts under study, each over a period of nine months. For all students in the population, these techniques involved a test at the beginning and the end of the course. Additionally, those students receiving learning support completed questionnaires during the life of the cohort.

ii. Cross-sectional data from pre and post-tests for the experimental and control groups. The control group comprised those students re-sitting their GCSE mathematics but not receiving learning support and the experimental group comprised those students re-sitting their GCSE mathematics who were also receiving learning support. The students were given an initial assessment at the beginning of the period and a mock examination towards the end, both being used as indicators of the students' performances at that time.

iii. Questionnaires were used after some selected tutorials to provide data on changes occurring during the course of the study.

3.3 Research methods

3.3.1 Introduction

This section details the techniques forming the methodological and time triangulation approach adopted for the research. These were:

i. Statistical.

ii. Questionnaires.

iii. Discourse analysis.

3.3.2 Statistical methods

Statistical techniques were used to:

i. Look for the factors affecting a student's performance and develop a model to predict the outcome of their GCSE course measured by their performance in their mock examination.

ii. Identify differences between the student and tutor's perceptions of a tutorial.

iii. Identify any significant difference between the performance of students receiving learning support and those who were not.

Statistical analysis was applied to both non-parametric and parametric data. The data collected fell into the following categories:

i. Non-parametric data on an ordinal scale (e.g. Likert scale), being defined as a scale on which data is shown simply in accordance with some order.

ii. Parametric data consists of data measured on both interval and ratio scales.

   a) An interval scale is defined as a scale of measurement of data in accordance with which the difference between values can be quantified in absolute but not relative terms and for which any zero is merely arbitrary. The scores of students in the attitude test falls into this category.

   b) A ratio scale is defined as a scale of measurement of data that has a fixed zero value and permits the comparison of differences.

(Borowshki and Borwein, 1989)

Table 3.3 summarises the data collected for statistical analysis. (See 'Data Collected' section for a detailed description).

Description of explanatory variable	**Scale of measurement**	**Type of data**
Gender	Nominal	Non parametric
Result in Numeracy test	Interval	Parametric
Result in Potential test	Interval	Parametric
Grade obtained in GCSE mathematics last time	Categorical	Non parametric
Level GCSE mathematics studied at previously	Nominal	Non parametric
Last school attended	Nominal	Non parametric
Result of Attitude test	Ordinal	Non parametric
Hours spent in workshop/lessons	Ratio	Parametric
Hours of learning support received	Ratio	Parametric
Result in Mock Examination	Interval	Parametric

Table 3.3: Statistical data collected.

Correlation.

Correlation techniques, which measure the extent of correspondence between two variables, were used for both relational and predictive studies. *"Their use being considered particularly appropriate when there is a need to discover relationships and/or where the objective is to make some degree of prediction"* (Cohen & Manion 1994).

Subject to the multiple linear regressions providing a model with a correlation coefficient of the order of 0.8 – 0.85, predictions of students scores could then be made for both students receiving learning support and those who were not, based on the model. A comparison could then be made to look for any significant difference.

Correlation techniques however have the following inherent weaknesses:

i. A correlation coefficient only implies concomitance and therefore does not establish cause and effect relationships.

ii. Correlation is less rigorous than the experimental approach as it exercises less control over the independent variables.

iii. It may appear to identify relationships that are in fact non-existent.

iv. The correlation coefficient is relatively imprecise being dependent on the accuracy of the measurement of the variables.

The following correlation techniques were used in the research:

a) Pearson Product Moment Correlation

During the early stages of the research the Pearson Product Moment Correlation was used to identify which of the independent variables (measured on a parametric scale), showed significant correlation with the dependent variable (i.e. the students' mock examination results).

The variables on which data were being collected for each student were:

i. Numeracy test

ii. Potential test

iii. Attitude test

iv. Hours spent in the mathematics workshop

v. Hours of learning support (if any) received by a student

By looking at the results of these in the form of scatter graphs (see Chapter 4) it was possible to see whether the relationship was approximately linear.

b) Multiple linear regressions

Multiple linear regression is a technique used to provide coefficients for each of the multiple variables, which can then be used to create a model in order to make predictions. Correlation coefficients are determined from the data and give an indication of the likely accuracy of the model as a predictor. The technique was used to develop a model that would allow predictions to be made of the outcome of students re-sitting their GCSE mathematics.

The benefit of this technique over simple correlation was summarised by Borg, (1963):

> *Since most correlations between the variables of interest in the social sciences are of the order of 0.50, relatively little confidence can be placed in such prediction in the individual case. It is, therefore, necessary to raise the correlation on the basis of which predictions are made in order to increase their precision. This can be done by refining the instruments used and/or the criterion being predicted and..... by combining a number of variables into a composite predictor of the criterion.*

This approach can only be used with parametric data. Since much of the data collected was of a non-parametric form it was necessary to transform it into a parametric form in order that it could be used in the analysis. For example 'last schools attended' were recorded and each of the local schools was given a score based on the average percentage of students achieving five grades C or higher at GCSE over the period that data was being collected (see section 4.2.1 for further details).

Data Collected

Cohen and Manion, (1994), commenting on correlation coefficients in the range 0.65 to 0.85, note that at the lower end of the scale they enable group predictions to be made with reasonable accuracy, e.g. the number of students that will pass an examination. At the higher end of the scale it allows for individual predictions to be made that are considerably more accurate than would have been achieved by guessing or by some chance selection process.

During the academic year 1998/99 the following data were collected for the complete cohort studying GCSE mathematics:

i. Gender.

ii. Previous grade attained for GCSE mathematics and the tier entered for the examination. For the students taking GCSE this was either at the foundation or intermediate tier.

iii. Previous school attended.

iv. Hours spent by the student in Exeter College's Mathematics Workshop, where students worked on a programme of self study assisted by tutors. This time did not include any time spent by the student in private study. During the second year of the research students were asked to give details of other time they spent studying and whether they were receiving any additional help beyond that given by the college. The responses from the students were considered by the author to be unreliable, as some of the figures returned by the students were thought to be excessively high. In addition the question of likely correlation between hours spent studying and outcome was discussed with Professor D. Burghes of the CIMT at The University of Exeter. He expressed the opinion that there was an optimum number of hours a week for a student to study mathematics and when this time period was exceeded students failed to derive any benefit. In the light of this and the outcome from the analysis of the first years results, which showed that there was no correlation between hours spent studying in the workshop and the result obtained by a student (see Table 5.7.) this matter was not pursued further.

v. The score students obtained on the attitude test developed by the author (see Appendix 3).

vi. Hours of learning support (if any) received by the student.

vii. Score in the mock examination, which was taken shortly before re-sitting their GCSE. It was necessary to use the mock score, as the examination board was not prepared to release the results of the GCSE examinations.

Following collection and analysis of the first year data, discussions were held with Professor D. Burghes regarding his use of tests to predict GCSE grades and the results obtained to date. Resulting from these discussions an Initial Assessment Test was introduced for the students in the following two cohorts. This test, divided into two sections, potential and numeracy, is a shortened version of that developed by the Mathematics Enhancement Project (MEP) at The University of Exeter. The original tests were designed for students sitting at foundation, intermediate or higher level with questions becoming progressively more challenging. As no students at Exeter College sit GCSE mathematics at higher level the more challenging questions were removed. Appendix 6 contains the version of the tests used.

Results from the MEP tests on a sample of approximately 5000 pupils yielded a correlation coefficient of around 0.7 between the test results and the students' final GCSE grade (Burghes 2000).

3.3.3 Questionnaires

Copies of the questionnaires referred to in this section can be found in Appendix 2.

a) Questionnaire 1 – Desktop Video Conferencing

After their first tutorial using DVC, the students were asked to complete a simple questionnaire comprising four open response questions. The intention was to record the student's first impressions of the equipment and the environment of DVC thus allowing a comparison to be drawn between their initial attitude to using DVC and their attitude towards it once they had become more familiar with it. The questions asked were:

i. How easy did you find it to operate the equipment?

ii. List the things you don't like about DVC.

iii. List the things you do like about DVC.

iv. Any other comments.

b) Questionnaire 2 – Assessment of tutorial

This consisted of two questionnaires, one completed by the tutor, the other by the student, independently and contemporaneously with the tutorial. The questionnaires contained matched questions based on Laurillard's (1993) twelve characteristics that need to be met by a medium such as DVC if effective teaching and learning is to take place.

The characteristics that the questionnaires sought to evaluate can be summarised as follows. The tutor relevant characteristics are that the tutor can:

i. describe conception,
ii. re-describe in the light of student's conception or action,
iii. adapt task goal in light of student's description or action,
iv. can set task goals,
v. set up world to give intrinsic feedback on actions,
vi. reflect on student's action to modify re-description.

Student relevant characteristics are that the student can:

i. describe a conception,
ii. re-describe in light of tutor's re-description or student's action,
iii. act to achieve task goal,
iv. modify action in light of feedback on action,
v. adapt actions in light of tutor's description or student's re-description,
vi. reflect on interaction to modify re-description.

Since the outcomes from these questionnaires might be influenced by factors other than the twelve criteria, questions were also included to identify where a difference between tutors might exist. Patrick and Smart, (1998), identified two key factors necessary for a teacher to be effective, namely the tutor's ability to challenge students and the tutor's organisation and presentational skills. Brown and Atkins, (1993), Entwistle and Tait,(1990) and Swartz, (1990), have also identified similar factors. Additional questions were included in the questionnaire to test these factors, so that in the unlikely event of one of the learning support tutors being found to be lacking in one of these two factors the data could be removed.

The questionnaires were used randomly for both face-to-face and DVC tutorials. To make the completion as random as possible, a number of weeks were chosen throughout the year and the four tutors participating were asked to complete the questionnaires with all the students they saw during that week. Each time the questionnaire was used the responses from the tutor and student were compared. All the pairs of responses for each question were then collated; those for face-to-face and DVC being separated. For each question the responses of the students and tutors were compared using a sign test to identify where a statistically significant difference existed.

From the analysis of these questionnaires any differences that may exist between the student and tutor's perceptions of a tutorial were identified; additionally any differences between DVC and face-to-face tutorials became apparent. The questionnaires were trialed during the academic year 1998/1999 giving near perfect correlation between student and tutor responses.

c) Questionnaire 3 – Final Questionnaire.

These questionnaires were designed to obtain feedback on DVC from students under two broad headings. The first part of the questionnaire was primarily intended to obtain students' views on any improvements they thought could be made to the equipment and its location. The second part of the questionnaire covered the tutorials. During the course of the research the author had formulated a number of conjectures as to why DVC was an effective method for delivery of learning support and had identified a number of differences between face-to-face and DVC tutorials.

The second part of the questionnaire sought collaboration of the observations and impressions gained by the author during the course of the research. These observations included:

i. The use of DVC allowed students to receive quicker feedback as a consequence of having a clear view of the whiteboard.

ii. DVC creates a relaxed environment for students to work in.

iii. Students were more focussed on the work.

This questionnaire also gave an opportunity to compare students' initial impressions of DVC with those they had at the end of the academic year.

For the academic year 2000/01 the questionnaire was sent to those students at the end of their course, who had received their learning support using DVC. They were completed by students anonymously and returned by post to the author. Only around half of the questionnaires sent out were returned and so for the following year some were administered as before but others were completed with the author present and used as the structure for an interview with the student.

3.3.4 Discourse analysis applied to mathematics tutorials

Introduction

The research tool developed was designed to evaluate mathematics tutorials conducted either using DVC or face-to-face. This allowed a comparison of the two techniques to be made, whilst at the same time providing a mechanism to identify any inherent differences between the two methods. In particular it would identify:

i. Differences in the structure and rate of the dialogues.

ii. The extent of non-verbal interaction.

iii. The amount and speed of the feedback from the tutor to the student.

For comparisons to be made a model was required, which would incorporate a set of benchmarks against which a tutorial could be assessed. The benchmarks were set on the precept that a tutorial must fulfil the criteria of a theoretical model and the dialogue must have a coherent structure i.e. the dialogue was not a series of meaningful but disjointed utterances as might occur when there were significant delays in data transmission.

The analysis did not seek to quantify the outcome or grade the tutorial, since to a large degree the outcome would be dependent on the skill of the tutor, but rather it sought to show whether the conditions necessary for a successful outcome had been met and to identify the key features of each type of tutorial.

The Development of the Model

The starting point for the development of a model was the Conversational Framework developed by Laurillard, (1993) (see section 2.2 for details). This had been developed specifically as a model for one-to-one teaching and establishes the criteria necessary for learning and teaching to take place. *"The list of required media characteristics is meant to encompass a complete specification of what is required of a learning situation and what can be offered by combinations of media"*(Laurillard, 1993).

Table 3.3 below summarises Laurillard's classification of the characteristics of the Conversational Framework. Each characteristic operates at one of four levels, these are:

i. Adaptation - an internalised action, which cannot be observed and results in modified action based on immediate experience.

ii. Reflection - an internalised action, which cannot be observed.

iii. Interactive at the level of description - Laurillard draws a clear distinction between discussion or action involving concepts which she describes as being at the level of description and those that are involved in achieving a task such as solving an equation. By description she means, for example, a discussion on the concept of integration as a process of summation.

iv. Interactive at the level of action – this is complementary to interactive at the level of description; an example would be evaluating an integral such as $\int_1^3 \ln x dx$.

Characteristic			
No.	Description	Nature /level	
5	T adapts task goal in light of S's description or action	Adaptation	Internal
10	S adapts action in light of T's description	Adaptation	Internal
11	S reflects on interaction to modify description	Reflection	Internal
12	T reflects on interaction to modify description	Reflection	Internal
1	T describes conception	Interactive at the level of description	Discursive
2	S describes conception	Interactive at the level of description	Discursive
3	T redescribes conception in light of S's conception or action	Interactive at the level of description	Discursive
4	S redescribes conception in light of T's redescription	Interactive at the level of description	Discursive
6	T sets task goal	Interactive at the level of actions	Discursive
7	S acts to achieve goal	Interactive at the level of action	Discursive
8	T's world gives feedback on action	Interactive at the level of action	Discursive
9	S modifies actions in light of feedback	Interactive at the level of action	Discursive

Table 3.4: Classification of the characteristics of the Conversational Framework

In practice it was found difficult to apply this general framework to the transcript of a mathematics tutorial for the following reasons:

i. Characteristics 5,10,11 and 12 are described as being internal; does this imply that they cannot be identified or observed by a third party? If this is the case then tracking a dialogue through the framework becomes disjointed. The author concluded that these characteristics were non-observable and should be identified as such and their occurrence must be implied from the observable characteristics. An example of this might be the situation where a tutor reflects on the last action of a student and decides to continue with the current line of discussion.

ii. In the description of characteristics 1,2,3 and 4, Laurillard uses the word conception. This is defined by the Oxford English Reference Dictionary as:

   a) An idea or plan, especially as being new or daring.

   b) (Usually followed by *of*) understanding; ability to imagine (*has no conception of what it entails).*

c) The facility of conceiving in mind; apprehension, imagination (Pearsall & Trumble 2001).

Using definition a) above, might suggest that an algorithm to solve simple equations is a conception, alternatively it could be argued that it is part of working at the interactive level.

Laurillard does not give an explicit definition of the word conception and how it might be applied. To make the framework subject specific and to avoid ambiguity in the use of the word conception, the following modifications to the Conversational Framework were made.

1) The framework was split into three sections:

i. Topic centred
ii. Non-observable actions
iii. Task centred

The intention of this was to distinguish between generalities and specific tasks that a student may be asked to carry out e.g. to distinguish between Pythagoras's Theorem (topic centred) and the application of it to a specific problem (task centred).

2) The use of the word conception was found to be problematic to define within the context of mathematics. The author therefore modified the framework with the word conception being replaced with concept, which is defined as follows:

Concept: - An idea or hypothesis applicable to the topic, theorems, rules, methods, algorithms, principles, notation and symbolic conventions.

A clear distinction could then be drawn between concepts and feedback generated during the tutorial resulting from the carrying out of tasks. For example, how to multiply out a bracket such as $3(2x + 5)$ would be classified as a concept, if the student gives the answer as $(6x + 8)$ then this would be corrected as part of the feedback from the tutor. Misconceptions would then be dealt with under the heading of concepts whilst errors or mistakes would be addressed under the heading of feedback.

3) As the Tutor is not the primary source of teaching, a decision box has been added to determine the starting point for the dialogue on any particular topic.

Incorporating these revisions produced the framework below. If this is compared with Figure 2.6 it will be seen that the main change is to split the framework into three clearly defined zones. (Changes made by the author to the framework are coloured dark red).

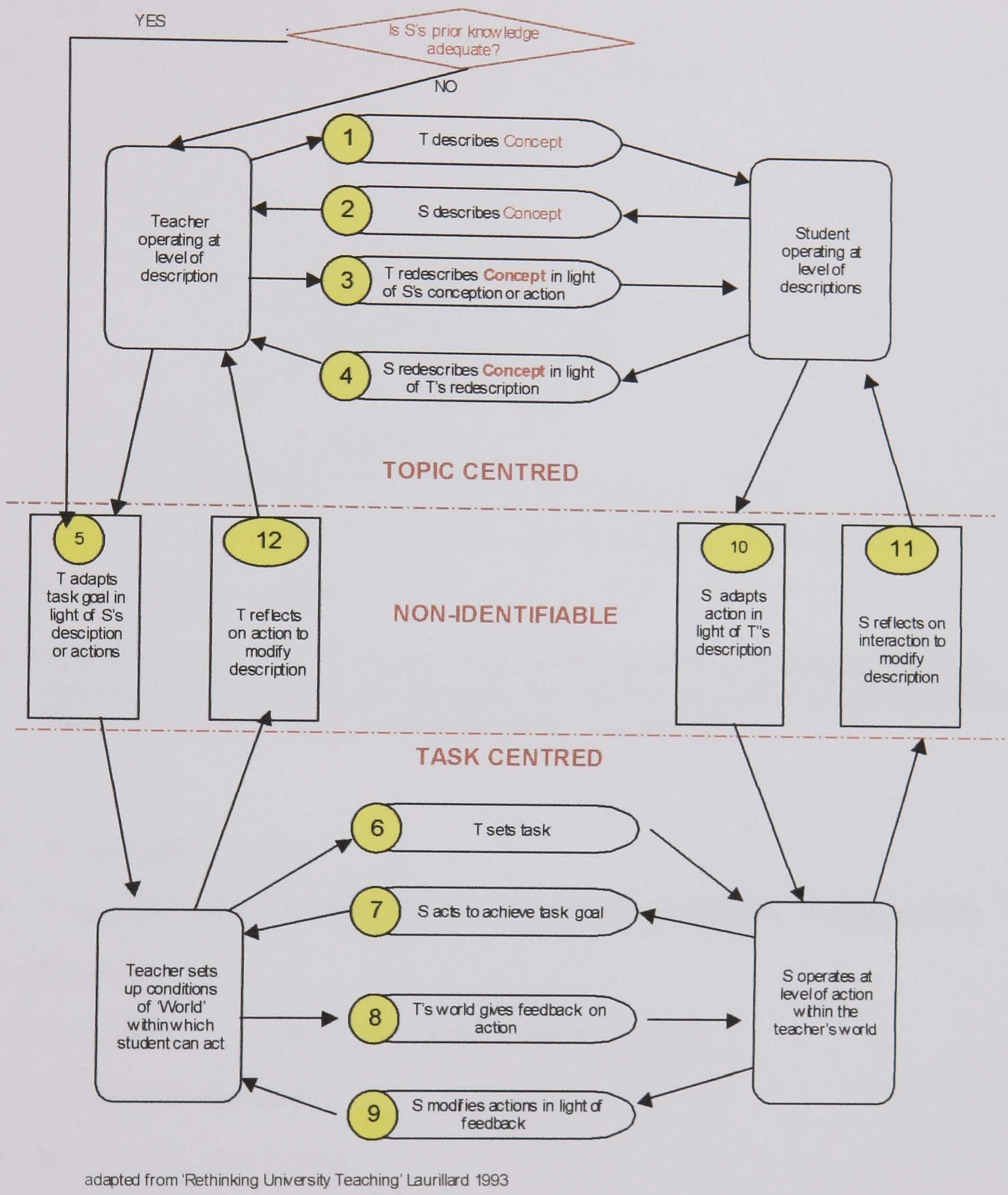
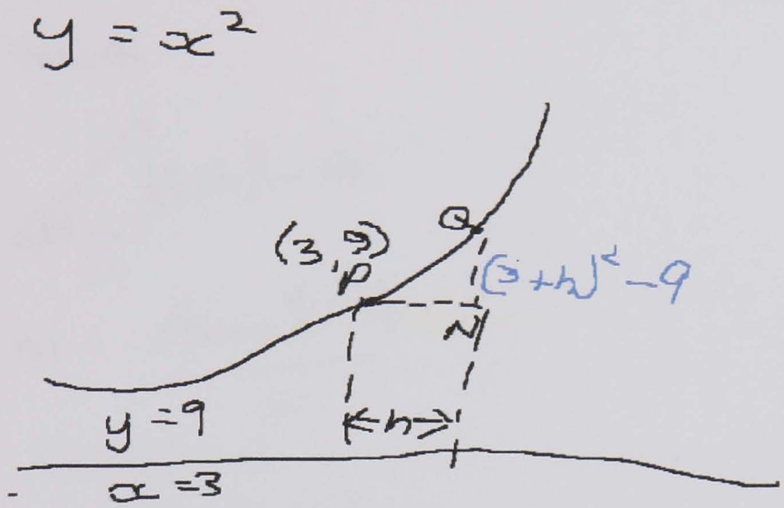


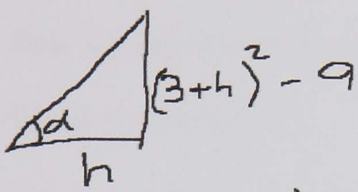
Figure 3.2: The first modification made to the Conversational Framework

The following extracts are taken sequentially from the transcript of a tutorial with an 'A' level student. This transcript was produced from an audio recording with reference to the electronic whiteboard saved at the time. This extract is analysed using the revised Conversational Framework

(Figure 3.2) with the characteristics identified with numbers in brackets, which refer to the components of the Framework.

T	Here we go. The first student is. …………I'll place this down there. Right OK M……… off we go.
S	Okay right, I thought we would have a look at differentiation  --
T	You have just started that?
S	Yeah we have only had one lesson on it and a lot of that was spent talking about fourth dimensions and the universe and things like that. ***So the whole point of differentiation is as I understand it is to find the gradient of a point on a curve (2)*** ………………………………………………………………………………………………
S	Yes the equation is; okay
T	I thought it might be something like that. I had a feeling it might be. Yeah okay, right
S	Right okay
T	So h is the…………what? The x distance between P and Q
S	Yes so then P (interrupted)
T	So where is P, has P gone up
S	P is at, actually do you; no you don't have the pure maths
T	No I haven't got it with me
S	All I know is $y = 9$, so I think $x = 3$.
T	Okay
S	You want to know the co-ordinates of
T	So that is your Q?

S	No that's just for the – I'm not sure what that is for
T	***Usually what you do is that say P is the point you were just talking about (3,9). Then Q will be a little bit further away from it. Like 3.1;*** **(3)**
S	Right
T	Is that what you were going to do?
S	***Erm yeah it's what I was going to do, the delta Y is $(3 + h)^2$ - 9 is what I have got down here*** **(4)**
T	That's fine



$$m = \frac{(3+h)^2 - 9}{h}$$

$(3+h)(3+h)$

$9 + 3h + 3h + h^2$

$$\frac{\cancel{h^2} + 6\cancel{h}}{\cancel{h}} \qquad \frac{\cancel{h}(6+h)}{\cancel{h}}$$

$h + 6 \qquad 6 + h$

$m = 6$

……………………………………………………………………………………………………

S	We're trying to find the gradient at point *P*?
T	That's right The idea, what will happen is that *Q* will get closer and closer to *P*. Your *h* at the moment is anything, just any old length, could be 1,0.1, 0.01
S	Yes, In the book it says where *h* is a low value
T	***Right okay, but what is going to happen is we will look what it is for a general h, when we know it is going to be small and then eventually let Q get closer and closer and closer to P, in other words let h get smaller. That's the limiting process; you've got to picture h getting tinier and tinier. As Q gets closer to P right, then this triangle becomes, the line joining P to Q will eventually become part of the curve. It will be so close that the straight line is almost indistinguishable from the arc of PQ on the curve. (1)***
S	Right. Okay.
T	***What you need to do is expand that, this thing on the top, (6)…*** I want you to expand this bit here
S	Right yeah
T	Tell me when…
S	Only I've got it here

T	You've got it there then that's cheating
S	I can do it, I mean it's just expanding brackets
T	Write it down anyway
S	***Right You've got $(3+h)^2$ so you're going to get $9 + 3h +3h + h^2$. so then you get overall because the minus 9 and the plus 9 will cancel out - you will get $h^2 + 6h$, I think (7)***
T	***Yes so the top is $h^2 + 6h$ that's fine. The 9s have gone; so don't forget to divide by h as well (8)***
S	Alright, then when you ....so then that's all over h, so then
T	What is that going to be
S	***That's going to cancel out with that*** (9)
T	So that becomes just h
	--

Figure 3.3: Extracts of transcript of a tutorial

The sections in bold italic text above are examples of the characteristics of the framework being met. However, this could not be considered satisfactory evidence that DVC adequately supports teaching and learning since this does not demonstrate that the dialogue took place within a coherent well-structured framework.

Laurillard, (1993), argues that satisfying the characteristics that might be applicable to a particular teaching situation is a necessary condition for teaching and learning to take place. However, unless this happened within the context of a well-structured dialogue, learning was unlikely to occur; that is to say you could have a series of statements that met the characteristics but were incomprehensible to the student because of the sequence or the way, they had been presented. This might occur for example if there were considerable delays in the time of audio transmissions, so that the tutor and student were in effect talking over each other.

The second consideration is that the Conversational Framework does not describe all that takes place during a tutorial and is not applicable to the whole of the dialogue of a tutorial. The following are examples of situations where Laurillard's characteristics cannot be used:

i. Discussion of the topic to be covered within a tutorial.

ii. Where a student raises a query e.g. Why can't I cancel the x's down in the expression $\frac{x+1}{x}$?

To check the structure of the dialogue it was considered necessary to look at the sequencing of the interaction of the tutor and student within the overall structure of the Conversational Framework. Whilst the analysis of the structure of the dialogue could be done independently of the Conversational Framework, integrating the discourse analysis into the framework gives one tool that could be used for the analysis of a tutorial. To do this, the elements of the exchange unit defined by Stubbs, (1983), (see section 2.3 for details), were added to the framework. This led to the framework shown in Figure 3.4.

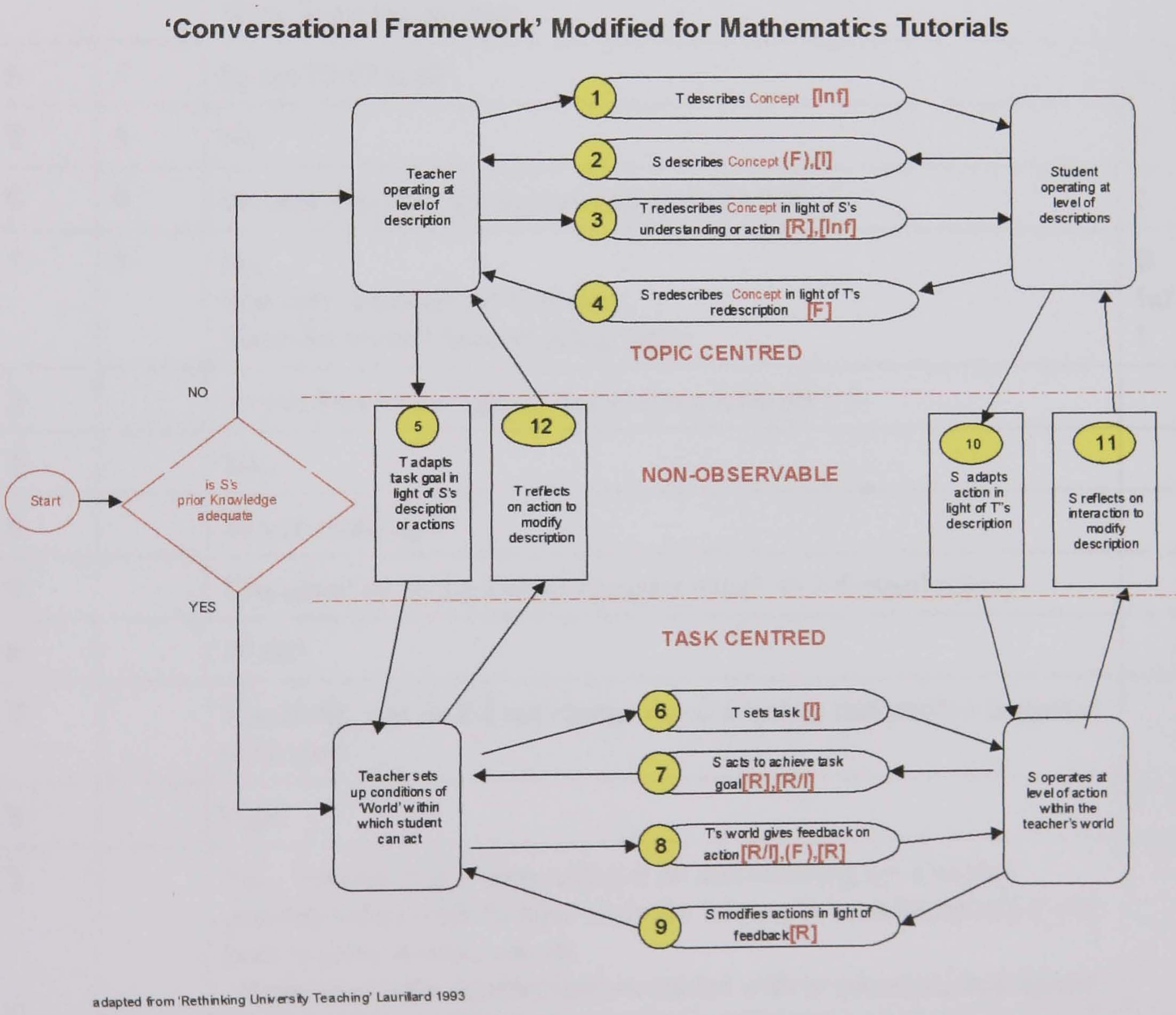


Figure 3.4: The second modification made to the Conversational Framework

Analysis of tutorials from transcripts together with the images of the whiteboards using this revised model, again, proved to be difficult to apply and produced results that were inconclusive.

The following extract is taken from a DVC tutorial with a GCSE student; the main topic was rounding off numbers. The whiteboard associated with this part of the tutorial is included after the transcript. By row five of the transcript it is becoming difficult to analyse accurately.

Participant	Characteristic	Dialogue	Discourse analysis	Row Number
T	6	Okay now here is a number, I'm going to write down how I want you to round it off. I want it to 2 dp, I want it to 1 sf, and I want it to 3 sf. Write down the answers.	I	1
S	7	Its not 29.67 is it?	I	2
T	8	No	F	3
S	9	Because you have got to round up so its 29.70?	I	4
T	8	No, You only round up the first digit. There the second decimal place, there	R Inf I	5
S		So you look to the right of that and you have got a 5		6
T		Yes,		7
S		So you round up?		8
T		You round up so the answer becomes what? to 2 decimal places		9
S		29.68?		10
T		Yes 29.68, you would not change that one unless that number happened to be nine		11
S		Right		12
T		Yes. You don't just keep rolling it on and rounding up. I've met students before who do that. Only the last one is rounded up and if you have to carry it over, you do. Right what's the number that we started with to one significant figure?		13
S		Well two is the first significant figure, isn't it?		14
T		Yeah, so what's it going to be to one significant figure?		15
S		30		16

T		Yes. Okay the answer to that is 30. Right what is that number to three significant figures?		**17**
S		Third significant figure is the 6		**18**
T		Right		**19**
S		So you round up, so its 30.1 isn't it?		**20**
T		No. No well the third significant figure is the 6, yes. You have got a 7 to the right of it, so to three significant figures the answer is 29.7. You don't keep rolling it along, right. The third significant figure was the 6. And the next, so that the one you've got to focus in on. The one to the right of it was the 7, which means you have got to have one on to the six, and then you stop.		**21**
S		Right		**22**
T		So the answer is 29.7. All right lets do another one because I'm not convinced you've got it yet.		**23**
Below is the white board that accompanied this part of the tutorial				

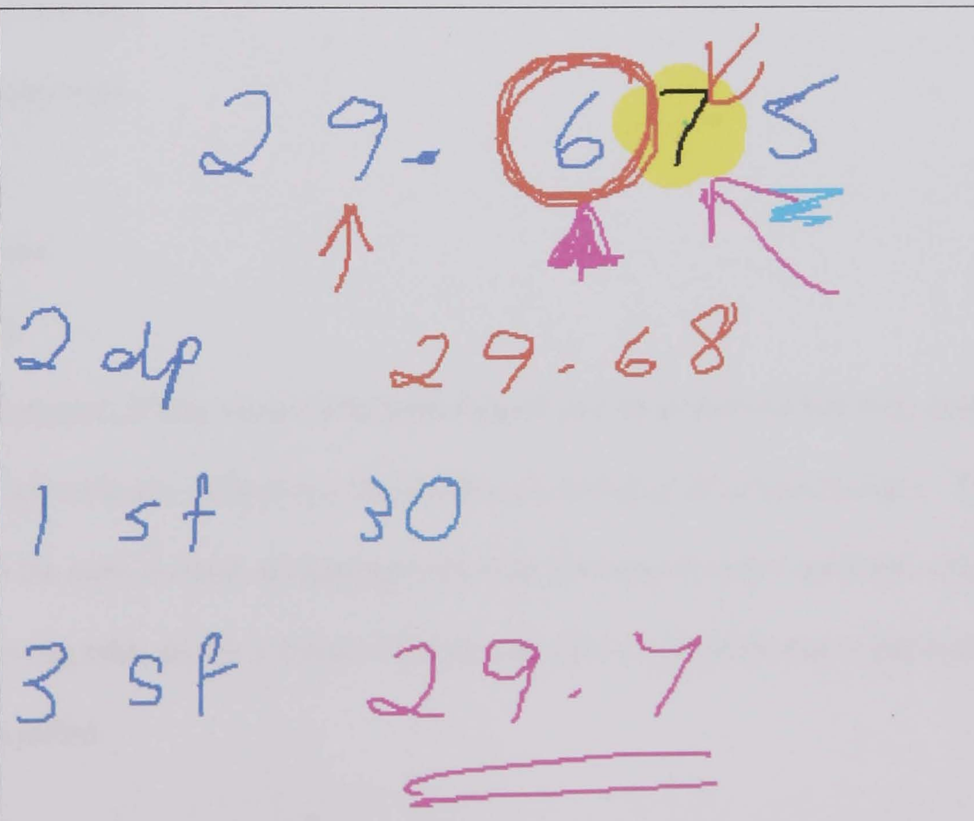


Figure 3.5: Transcript of part of tutorial (verbal communication only)

It is apparent, from row five of Figure 3.5 above, that part of the dialogue is being lost. For example, what does the use of the word 'there' twice in the third row refer to? With the whiteboard image added it could be seen that the tutor is indicating the location with arrows.

Thus far the method has failed to recognise the non-verbal communication that takes place particularly that which might be described as non-linguistic, for example, such things as the information conveyed within a diagram.

Literature in the field of discourse analysis tends to focus on language to the exclusion of non-linguistic communications (Stubbs, (1983), Sinclair & Coulthard, (1975)). It was realised this non-linguistic communication might form a significant part of the interchange between student and tutor, which by definition does not form part of the discourse. With DVC this non-verbal communication took place primarily on the whiteboard, which was used for the major part of any tutorial (around fifty five minutes of each hour). The versatility of the whiteboard allows this non-verbal communication to take a number of forms. Non-verbal communication will typically take the form of:

i. Diagrams to help explanation of a topic.
ii. Written examples.
iii. Written questions.
iv. Prompts.
v. Corrections.
vi. Feedback.

For the purposes of this research the definition of discourse analysis has been modified to include all those acts of a non-verbal type that can be considered to be communication. These have been classified in the same manner as language within the framework of the exchange units.

The following table shows a number of these non-verbal communications and how they have typically been classified.

Non-linguistic Communication	Classification
Diagrams	[I] or [Inf] when used in the explanation of a topic or question. [R] when used as a follow-up to a student's action
Written examples	[I] or [Inf]
Written questions	[I]
Prompts	[R/I]
Corrections	[R]
Feedback	[R] or [F]

Figure 3.6: Classification of non-linguistic communication

The model that evolved changed from being a Conversational Framework to a 'Framework to Model Interactions'.

In order to apply this extended definition of an exchange unit the method of analysis changed from using transcripts and the whiteboard images to using video recordings. Each verbal and non-verbal action was then classified and recorded against a time frame. To distinguish these from verbal communications a notation of underlining was used (e.g. [I]).

This final modified version of the Conversational Framework was the one used in the research for analysing tutorials.

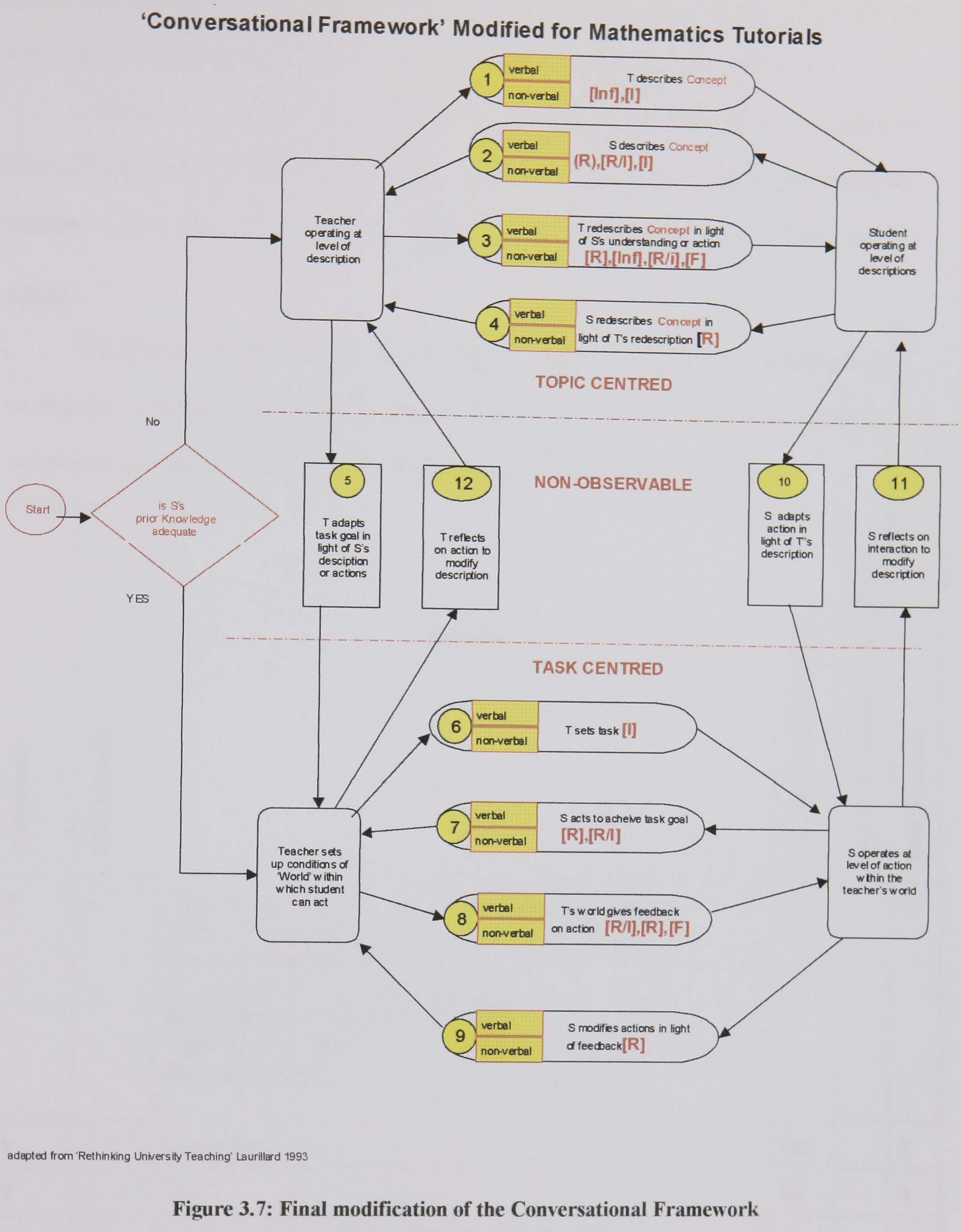


Figure 3.7: Final modification of the Conversational Framework

The tutorial was recorded into one of the computers being used for the DVC session. The recordings were then analysed with each verbal and non-verbal action being noted. The method produced large files (typically 650-1000Mb) that were difficult to handle. More satisfactory results were achieved using another computer fitted with a web cam and recording the screen and audio of the computer used for the DVC; at the same time the whiteboard images of the DVC session were saved. A similar method was used for face-to-face tutorials; in this case the paper being written on was kept as a record and the web cam used to record the sequence of writing on the paper.

Once the research had reached a point where two substantive differences between the two forms of tutorial had been identified, i.e. the amount of non-verbal communication and the rate of response from the tutor to the student, further analysis of tutorials focussed on just these two aspects.

To illustrate the effect of the inclusion of non-verbal communication on the analysis of a tutorial, the section of transcript quoted above is reproduced below. To this has been added the non-verbal communication in the form of the whiteboard with author's comments in italics.

Participant	**Characteristic**	**Dialogue**		**Discourse analysis verbal**	**Discourse analysis non- verbal**	**Row Number**
T	6	Okay now here is a number, I'm going to write down how I want you to round it off. I want it to 2 dp, I want it to 1 sf, and I want it to 3 sf. Write down the answers.	*Tutor writes the question* 29.675 2 dp 1 sf 3 sf	[	I	1
S	7	Its not 29.67 is it ?		**R/I**		**2**
T	8	No		**F]**		**3**
S	9	Because you have got to round up so its 29.70?		[		**4**
T	8	No you only round up the first digit,		**R**		**5**
	8	There the second decimal place, there	*Tutor highlights the 7* 29.675 2 dp 1 sf 3 sf	**R**	**R**	6

	8	So you look to the right of that and you have got a 5	*Tutor emphasises the 5* 29.675 2 dp 1 sf 3 sf	**R**	**R**	**7**
S	9	Yes, so you round up?		**I**		**8**
T	8	You round up so the answer becomes what?, to 2 decimal places		**R/Ir**		**9**
S	9	29.68?		**R**		**10**
T	8	Yes 29.68,	*Tutor writes down answer* 29.675 2 dp 29.68 1 sf 3 sf	**F**	**F**	**11**
	8	You would not change that one unless that number happened to be nine	*Tutor first indicates the number that would not be changed (by ringing it) and then the number that might be 9 (by means of two arrows)* 29.675 2 dp 29.68 1 sf 3 sf	**Inf**	**Inf**	**12**
S		Right?		**R**		**13**
T	3	Yes. You don't just keep rolling it on and rounding up. I've met students before who do that. Only the last one is rounded up and if you have to carry it over, you do.		**Inf**		**14**
	6	Right what's the number that we started with to one significant figure?		**[I**		**15**
S	7	Well 2 is the first significant figure, isn't it?		**R/I**		**16**
T	8	Yeah, so what's it going to be to one significant figure?		**R/Ir**		**17**
S	9	30		**R**		**18**
T	8	Yes. Okay the answer to that is 30.	*Tutor writes answer in* 29.675 2 dp 29.68 1 sf 30 3 sf	**F**	**F]**	**19**
	6	Right what is that number to three significant figures?		**[I**		**20**

S	7	Third significant figure is the 6		R		21
T	8	Right		F]		22
S	9	So you round up, so it's 30.1 isn't it?		[I		23
T T	8	No. The third significant figure is the 6, yes!. You have got a 7 to the right of it, so to three significant figures the answer is 29.7.		R		24
	8		*Tutor adds arrow pointing to the 6* 29.675 2 dp 29.68 1 sf 30 3 sf		R	25
	8	The third significant figure was the 6; and the one next to it is the one you've got to focus in on. The one to the right of it was the 7, which means you have got to add one on to the six, and then you stop.		Inf		26
S		Right		F]		27
T	8 6	So the answer is 29.7. All right let's do another one because I'm not convinced you've got it yet.	*Tutor writes in answer* 29.675 2 dp 29.68 1 sf 30 3 sf 29.7	[Inf I		28

Figure 3.8: Transcript of part of tutorial with non-verbal communication added

Carrying out analysis using the above method is extremely time consuming. An alternative approach was just to consider the structure of the dialogue without considering the detail. For this a tutorial analysis sheet was used. The following example takes part of the dialogue above and tracks it using this sheet. The following notation was used in this analysis:

i. Shaded rows are for verbal communication, un-shaded rows for non-verbal communication.

ii. A **0** in a row indicates that an exchange of the form in the left hand column has taken place.

iii. The arrows indicate the sequence of the exchanges.

iv. The bottom row shows the analysis of the exchanges using Stubbs', (1983), classification.

1	T describes concept	V										
		Nv										
3	T redescribe concept	V										
		Nv										
6	T sets task	V	0									
		Nv	0									
8	T gives feedback	V			0		0	0		0		0
		Nv						0				0
2	S describes concept	V										
		Nv										
4	S redescribes concept	V										
		Nv										
7	S acts on task	V		0								
		Nv										
9	S modifies action	V				0			0		0	
		Nv										
			[I	R / I	F]	[I	R	R]	[I	R/Ir	R	F]

Figure 3.9: Example of tutorial tracking sheet

By reference to the last row it can be seen that this section of the dialogue is well structured as the criteria for acceptable exchange units have been met. This approach also has the advantage of easily being able to track the number of non-verbal actions. A time scale can also be recorded and hence the rate of non-verbal actions compared.

3.3.5 Interviews

Cohen, Manion and Morrison, (2000), have identified three possible functions of interviews. These can be summarised as:

i. The principal research tool for collecting data.

ii. A tool to test or modify hypotheses.

iii. One of a number of research tools to provide corroborative evidence.

It is for the third of these reasons that interviews were used in the later phase of this research because, as Kerlinger, (1970), suggests, they might be used to follow up unexpected results, or to go deeper into the motivation of respondents and their reasons for responding as they do.

A number of interviews were conducted with students as a follow up to their responses to the Final Questionnaire. Using Patton's classification of interview types (1980), the interviews fell between 'Informal conversational interviews' and 'Interview guide approach'. The characteristics of these two types of interview are:

Informal conversational interviews - *"Questions emerge from the immediate context and are asked in the natural course of things with no predetermination of question topics or wording"*

Interview guide approach - *"Topics and issues to be covered are specified in advance, in outline form; interviewer decides sequence and working of questions in the course of the interview".* (Patton, 1980)

The interviews were semi-structured in that the students were advised in advance that the interviews would follow the questions in the Final Questionnaire.

Questioning followed the same order as the questions on the Final Questionnaire. Further supplementary questions were asked if the interviewer felt it necessary to probe more deeply into the answers given by a student. The intention was for the interviewer to gain a better understanding of the students' replies to the questionnaire and their perceptions of DVC, in particular the differences between DVC and face-to-face tutorials. The interviews were, with the consent of the students, recorded and subsequently transcripts were produced of relevant or illuminating comments made by the students.

3.3.6 Attitude Test

Introduction

Attitude being an abstract concept tends not to be fixed.

> *Cognitive theories mainly see attitudes as associative networks. Some researchers suggest that attitudes work as mental representations within a human's mind. These mental representations consist of a thought or knowledge unit that is associatively connected to an affective unit. These association-links exist both within attitudes and between different attitudes. Through a process of spreading activation "old" thought or knowledge units and emotions from an attitude may easily be connected to new nearby elements. This may cause a "new attitude toward a certain element to occur as a consequence of being associatively connected to an old attitude.*
> (Tesser and Shaffer 1990).

A student's attitude to any particular subject will possibly change during the duration of their studies. It seemed likely that the students' initial attitude towards their studies would be one of the factors affecting the outcome of their re-sitting GCSE mathematics.

The development of the Attitude Test used here was based on the procedures detailed in "How to Measure Attitude", Henerson (1987). The following is a brief summary of the procedure. Firstly, decide on the type and format of the attitude test to be used, working through the following list:

i. Identify the programme objectives for which the questionnaire is being proposed; determine which specific information you hope to obtain from the questionnaire.

ii. Choose a response format.

iii. Identify the frame of reference for the respondents.

iv. Write the questions.

v. Prepare a data summary sheet.

vi Critique the questions, try them out and revise if necessary.

vii. Assemble the questionnaire.

viii. Administer the questionnaire.

As the size of the cohort each year was relatively large and because of the flexible nature of students' attendance at the 'workshop' an Attitude Rating Scale was considered the most appropriate instrument. An attitude rating scale is derived from a particular form of questionnaire and gives a single score that indicates both the intensity and direction of a person's attitude (see Appendix 3). The Objectives of the test were to assess:

i. A student's attitude to mathematics in general and specifically as it might affect their future plans and aspirations.

ii. A student's appreciation of the impact on them should they fail to achieve a better grade.

Procedures for the development of an Attitude Rating Scale measured on an agreement scale

Stage 1. Constructing and using an agreement scale

1) Accumulate a large number of clearly favourable and unfavourable statements about the subject for which the test is designed (approximately 60 are recommended).
2) Ask a pilot group to respond to the statements using a Likert agreement scale. The respondents were chosen from a broad cross section of the college population to ensure that the whole range of attitudes was included. The extremes of the population were 'A' Level mathematics and GNVQ art and design students, ensuring a broad sample of students with differing aspirations.
3) Responses were scored on a point scale of 1-5, five for the most favourable with responses being scored dependent on whether the statement was positive or negative.
4) The score for each student was computed by totalling the points corresponding to each statement.
5) The top and bottom 25% of scores were identified and the remainder discarded. This was done so that only those students with strong attitudes in either direction were included in the analysis.
6) " Item analysis" (see Henerson, (1987) for details) was used to identify those statements providing good discrimination between the high and low scorers. The effect of this process was to remove the statements to which students' responses showed indifference. The statements that evoked strong reactions from the students were retained.
7) The questionnaire was constructed using the statements retained after step 6.
8) The modified questionnaire was then administered to the GCSE mathematics cohort.
9) The score for each respondent was computed and included with the other data being used for the multiple linear regression analysis.

The final version of the questionnaire is included as Appendix 3.

Stage 2. Checking the Reliability and Validity

"Validity normally implies reliability, conversely reliability does not imply validity."

(Henerson, 1987)

Reliability

The instrument was administered to the same group twice with an interval of one month and the correlation between the responses was determined. A large variance within the group is needed and was achieved by targeting two specific sub-groups whose attitude towards mathematics was likely to be different. *"High variability in your sample helps to increase the chances of demonstrating high reliability in your instrument"*(Henerson, 1987).

The correlation between the first and second responses gave an overall correlation coefficient of 0.995. The implication of this result is that the test should be reliable in the sense that the test applied on different occasions should yield the same results.

Validity

"A valid instrument is one that has demonstrated that it detects some 'real' ability, attitude or prevailing situation"(Henerson, 1987).

Henerson,(1987) identifies the following threats to validity:

i. The inevitably weak link between attitudes and behaviour - research has failed to demonstrate a strong connection between the two.
ii. Response bias - due to a desire to please.
iii. Lack of comprehension or self awareness - not understanding the questions.
iv. Lack of objectivity in administration.
v. Too few items in the instrument.

Henerson defines four ways of demonstrating validity, defined as follows:

i. Construct validity - seeks agreement between a theoretical concept and a specific measuring device or procedure.

ii. Content validity - the extent to which the questions in a test both cover everything the test purports to measure and do not require other skills.

iii. Concurrent validity- established by the degree of correspondence between two different measures.

iv. Predictive validity - the extent to which a test predicts performance on a variable that is closely related to whatever it purports to measure.

(Sutherland, 1995)

The most appropriate of these for this research was considered to be concurrent validity. *"The concurrent validity is established by collecting data to see if the results obtained with the instrument agree with the results from other instruments"*(Henerson, 1987).

Concurrent validity was determined by calculating the correlation between the scores obtained in the attitude test and those obtained in the examination. Reliability of the test was further checked by using Cronbach's alpha measure. This is technically not a statistical test but rather a coefficient of reliability or consistency (UCLA, 2003).

Cronbach's alpha is given by the following formula, $\alpha = \frac{N \times \bar{r}}{1+(N-1)\times \bar{r}}$ where N is equal to the number of items (in this case 252) and $\bar{r}$ is the average inter-item correlation among the items. The test returned a value of 0.8516, which is considered as "acceptable" (Henerson, 1987).

3.4 Summary of the research objectives and methodology

The primary aim of this research was to evaluate the effectiveness of DVC tutorials (this did not include the technology used) and secondly to assess and quantify the effectiveness of learning support where provided to a student. The research was carried out as a longitudinal study of the cohort analysis type and included a number of different research approaches. This triangulation allowed both qualitative and quantitative research methods to be used thus avoiding exclusive reliance on one method or method bias by the researcher.

The experimental design of the research used the conventions of Campbell and Stanley, (1963), and the internal and external threats to experimental validity as identified by Campbell and Stanley,(1963), and Bracht and Glass,(1968), were considered.

The research methods used were:

i. Statistical analysis, which included both non-parametric data such as gender and last school attended, and parametric data gained from the results of Numeracy and Potential tests.

ii. Questionnaires of which there were three phases; Questionnaire 1 was designed to give an insight into the students initial responses to using DVC; Questionnaire 2 was given to both students and tutors and contained matched questions based on Laurillard's Conversational Framework. Questionnaire 3 asked students at the end of their course what they felt about the DVC tutorials and the equipment used.

iii. Discourse analysis was applied to the transcripts of tutorials using Stubbs' Exchange Units as a means of comparing face-to-face tutorials with DVC tutorials and as a mechanism to spot any inherent differences between the two tutorial methods.

iv. Interviews followed up on the responses given to the final questionnaire as a means to provide corroborative evidence.

Chapter 4 Results from questionnaires and interviews

4.0 Introduction

The results section of this report has been divided into three chapters, each chapter focusing on one of the three strands of the triangulation methodology discussed in Chapter 3. The three methods of collecting data were:

i. Questionnaires and interviews, which are considered in this chapter.

ii. Statistical data, which is considered in chapter 5.

iii. Discourse analysis, which is considered in chapter 6.

This chapter considers the results from the three different questionnaires and one phase of interviews. The first questionnaire looked at student and tutors' initial responses to using DVC after one session and contained four open questions. The aim of this questionnaire was to measure the initial reactions of both the students and the staff and in particular to identify any issues that arose during the first sessions. The second, which was designed in two formats, one for tutors and a simplified version for students, consisted of paired questions on a Likert scale. This questionnaire aimed to compare students and tutors perceptions of the tutorials, in order to determine whether or not the criteria set out in Laurillard's Conversational Framework were being met. The third questionnaire asked the students questions about such things as the equipment used during DVC tutorials and their opinions of their learning experience using this medium. This questionnaire was designed to require the students to reflect on their learning with DVC over a period of time and the results were to be compared with the findings from the initial questionnaire.

4.1 Questionnaire 1 Students and tutors initial impressions of DVC

All of the students who had received learning support using DVC during the second and third years of the data collection period (academic years 1999/2000 and 2000/2001) were asked to complete this questionnaire at the end of their first DVC session. A total of twenty-five students completed this questionnaire, twenty-three of who had received learning support from the author plus an additional two students who had worked with a second tutor. This tutor was also asked to complete the questionnaire in order that a comparison could be made between his impressions and those of the author. The second tutor was using DVC for the first time, while the author had been working with the system for at least one academic year and subsequently had much more experienced. The questionnaire (see Appendix 2.1) contained four open questions, and was designed to record the students and the second tutor's initial impressions of both the equipment and the method of tutorial.

All the students who completed the questionnaire were studying mathematics at one of four different levels: nineteen at GCSE level, three at HE access level, two at 'A' level and one at International Baccalaureate level. This broadened the research field to include impressions from different age and ability groups. None of the students had any previous experience of using DVC.

The results from these questionnaires were analysed using key words or phrases and responses categorised accordingly. A summary is presented in Table 4.1 (Appendix 2.1.1 lists the responses of all twenty-five students to each question). The responses from the second tutor and the two 'A' level students working with him are replicated in full in Tables 4.5 and 4.6. These two sessions were also recorded and transcripts produced for further analysis.

4.1.1 Students initial impressions of DVC

Key word/phrase	Percentage
Easy or very easy	76%
Reasonably/ Quite/fairly easy	24%

Table 4.1: Responses to Q 1- How easy did you find it to operate the equipment?

Table 4.1 summarises the responses of all twenty-five students to the open question "How easy did you find it to operate the equipment?" The results show that there were no negative responses and that all students were able to use the equipment and carry out essential operations such as connecting to the tutor. The author had anticipated that making this connection could be problematic and had put in place steps to avoid any problems.

Initial technical troubleshooting

Factors that aided the students' use of DVC were:

i. Simplifying the process of connecting to the tutor, as far as the limitations of the system would allow. The need for this became obvious to the author during the first year of research when it was apparent that many tutees did not have the level of competency in computer skills that had been anticipated. The method of connection varied depending on whether ISDN (2nd year) or broadband (3rd year) was being used. When using ISDN the students were given detailed instructions on how to connect to the tutor. To avoid the students having to boot up the computer it was left permanently switched on with a password-protected screensaver. Having cleared the screensaver the students had to simply select dial list in the 'Conference Manager' window and then click on the name of the tutor whereupon the connection was made automatically. When Broadband was used no costs were incurred for calls and so the tutor established a connection to the student's computer prior to the appointed tutorial time. This meant that on arrival the student had to simply put on the headset and commence the tutorial.

ii. Control of the software by the tutor. At the outset of the research it became apparent that the IT skills of the average student were minimal, for example many could not minimise a window. The tutor managed the NetMeeting software and the control of operations, such as opening the whiteboard and moving to new pages, which meant that the student was able to focus on the teaching and learning rather than the technical aspects of DVC. As students became familiar with the operation of the software they were encouraged to use the tools within it. Other research projects involving DVC have mainly focussed on its applications within the context of Higher Education with students who have been proficient computer users. Thus the problems encountered here due to students with poor computing skills have not been reported in earlier research.

Negative responses to using DVC

Key word/phrase	Percentage
Technical and equipment problems	48%
Not seeing tutor all the time/ seeing myself on the screen	8%
No comment	44%

Table 4.2: Responses to Q 2- List the things you don't like about DVC.

Table 4.2 summarises the students' responses to the question "List the things you don't like about DVC." The table shows that nearly half of the students found nothing to criticise at the end of the first tutorial. This indicates that, despite it being an unfamiliar experience, it was a positive one and left them with a good first impression of the system. The minor technical problems which existed in the initial stages of the research e.g. connection failures between computers, software errors and an echo in the headset, were all satisfactorily resolved during the course of the study.

In addition to the problems described above, one student was critical of what they perceived as the intrusive nature of the camera. Despite attempts by the author to stress that little use would be made of the video image, this did not remove the sense of intrusion felt by this student. It should be noted that the video image was used for less than 10% of the tutorial.

Positive Responses to Using DVC

Key word/phrase	Percentage
User friendly/ fun/ novel/ easier to work this way	56 %
Relaxed less stressful/ being alone	16 %
Easy to write and correct	4 %
The DVC package/ pen/ no paper/ easy to hear	34 %
The Learning experience/ a lot	12 %

Table 4.3: Responses to Q 3-List the things you like about DVC.

Table 4.3 summarises the students' responses to the request "List the things you like about DVC" (it should be noted that some students made more than one comment and so the percentages do not total to 100). The students' responses recorded in the table, together with the author's observations, highlighted a general consensus amongst students that DVC represented a pleasant environment in which to work and one that was less stressful than face-to-face tutorials. There was a strong sense from the students' comments that it was a good experience with over half of the students making positive comments about this mode of working.

Sound quality was identified as a positive feature by two of the students, who commented that they found it easier to hear what the tutor was saying. This may be as a result of a number of contributing factors:

i. When wearing headphones the high level of background noise in the Student Drop in Centre was effectively reduced.

ii. The blocking of external noise meant that the students had fewer distractions than those around them and so were more focused with a greater level of concentration.

iii. The students' computer was separated from the main teaching area by an acoustic screen 1.8m high with no door. This seems to have provided a good environment in which the students could work with seclusion, but without total isolation.

Even at this early stage some students had recognised some key differences between DVC and face-to-face tutorials, which the subsequent questionnaires and interviews identified, these are discussed in detail in section 4.3. The key differences identified by students from a pedagogical perspective were centred on the feeling that DVC provided a less stressful method of learning. Students said that they felt under less pressure when using DVC than they would have done if had they been sitting next to a tutor. Being physically distanced from the tutor seemed to create a more relaxed learning environment for the students. This is evidenced by student comments such as, "*it was less stressful than a normal lesson*" and "I *feel relaxed as I am not with someone, I do not feel too pressurised*".

Another factor, which contributed to the perceived reduction in the stress felt by students, was the management of the software by the author. He was able to make instantaneous corrections on the whiteboard whilst the student worked on the task, which would not have been possible in the same way, when working with paper. As DVC afforded the tutor an uninterrupted view of the whiteboard, he was able to give spontaneous feedback both verbally and visually via the whiteboard. Student 18 confirmed this with the comment "*I like the easy and clear way in which I can write and that the tutor can correct any mistakes I make*".

Student number	Comments
10	Tres bien
12	Feel positive about the process and look forward to next week. Like style of teaching and the tutor seemed patient with my attempts at understanding
16	A good use of technology in education
20	I now look forward to learning more next week

Table 4.4: Responses to Q 4-Any other comments?

Table 4.4 lists all the freeform comments made by students in response to the opportunity to make 'Any other comments'. It should be noted that no negative comments were made by any of the students. The freeform comments in Table 4.4 show a very positive student attitude to their first tutorial and represent a good start. No student asked to change to face-to-face tutorials during the course of the study, although this was offered as an option from the outset of the research. No student receiving support face-to-face asked to change to DVC and to the author's knowledge none was offered the opportunity.

Respondent	Question Number	Responses
A level student 1	1	It took a little time to get used to using the pen and tablet to write with, but it was easier after a short time. Talking was easy using the microphone.
	2	It was good because I could talk to the tutor and he could talk back, just as if he was sitting next to me. The way we shared the whiteboard was also similar, and made it not much more difficult than normal
	3	The pen and tablet was a bit tricky to use and still write as clearly as you can normally
	4	Overall using DVC was not very different from sitting next to Phil, as we still worked at the same pace.
A level student 2	1	It was fairly easy once we got into using the software
	2	Not being able to point to things on the screen without making a permanent mark
	3	I was able to do almost everything I could do in a normal session
	4	I think I spent more time working and less talking about other things

Table 4.5: Questionnaire responses from 'A' level students working with the second tutor.

Table 4.5 shows the results of the questionnaire completed by two 'A' level students working with the second tutor. Both students chose to make comparisons with face-to-face tutorials despite this not being directly mentioned by the tutor and both commented on the amount of work done during the tutorial. The comments regarding the use of the pen and pointing are attributed to the tutor's inexperience with the system and not being aware of the pointer built into the software.

The key findings from this student questionnaire were:

i. Students found the equipment easy to use.

ii. The majority of students enjoyed the experience and found it less intense than working face-to-face with a tutor.

iii. The video image was of sufficiently good quality to not warrant comment.

iv. Students liked being distanced from the tutor.

v. The sound quality was good.

4.1.2 Second tutor's initial impressions of DVC

Respondent	Question Number	Responses
Second Tutor	1	I had practiced on the whiteboard before using it, just to get used to the positioning and use of the tools. This was very useful and it was fairly straightforward to use with a 'live' student.
	2	Sense of remoteness from the student. Student asked for a copy of the work on the screen and I was not sure if this was possible. If not then it would be a serious problem, as they like to take something away from the session. Difficult when equations disappear off the top of the screen when doing a longer problem.
	3	Can always see the work the student is working on. No need to lean over to see the work. Easier to point out where things are going wrong or to point out important aspects with the highlighter. No distractions for student by seeing/hearing others working in the same room.
	4	Needs a high degree of concentration from both the student and teacher. Would be good to have some test or problem sheet at both ends, rather than doing the sessions 'cold'. Time seemed to go very quickly.

Table 4.6: Questionnaire responses from the second tutor.

Table 4.6 records the second tutor's initial, mixed responses to DVC; he had no previous experience of using DVC. The tutor's comment concerning the high degree of concentration needed by the student was also the initial impression of the author. However this is at variance with the students' responses, which showed that 16% of them felt more relaxed and/or less stressed using DVC. Undoubtedly the higher degree of concentration makes the tutorial more demanding for the tutor, attributed to having to concentrate on both the function of the computer and the tutorial itself and is in agreement with the findings of Jennings *et al.* (1998). The tutor also comments on the ease with which students' work can be viewed and feedback given, using tools such as the highlighter. Again this is the impression of the author and is considered to be a distinct advantage of the system.

4.2 Questionnaire 2 Tutor/student questionnaires

This questionnaire consisted of two separate parts (see Appendix 2.2), one completed by the tutor and the other by the student at the end of a tutorial. The questionnaires were completed by the two participants independently of each other and placed in a sealed box. Using information at the head of the questionnaire these were subsequently paired by the author. The questionnaires were designed to test whether:

i. The characteristics of the Conversational Framework were being satisfied.

ii. There were any discrepancies between tutor and student perceptions of how well the characteristics were being met in each tutorial. For example, the tutor may have felt that clear objectives had been set for the session, whilst the student may have felt they were not sure what the tutorial was intended to cover.

The statements in the questionnaire were based on the characteristics of Laurillard's Conversational Framework. The wording for the student questionnaire was simplified to make the intention of the statements more accessible to them. The questionnaires were trialled during the academic year 1998/9 by interviewing a sample of students and asking them what they understood by the statements on the questionnaire. The wording was further modified in the light of feedback from these interviews. The results that follow are for those obtained using the final version of the student questionnaire.

The questionnaires used a Likert scale of 1 to 5. A Sign Test was used to identify any significant difference between the tutor and student responses. A 5% significance level was used throughout. Whilst the choice of the significance level was an arbitrary one, 5% is the one widely used by researchers working in the social sciences (Haber and Runyon, 1973). A 'Y' in the middle column in each of the following tables indicates that there was a significant difference between the responses of the tutors and students.

103 pairs of questionnaires were completed during the course of the study. The questionnaires were completed during particular weeks of the academic year, which had been chosen by the author to be approximately in the middle of a term, but avoiding any disruptions such as examinations or work experience. The same tutors completed the questionnaires during academic periods. Table 4.7 shows the breakdown of questionnaires completed.

	Academic Year(s)			
	1998/9		1999/2001	
	DVC	Face-to-face	DVC	Face-to-face
Number of pairs of questionnaires completed	Nil	33	36	34
Number of tutors		4	1	4

Table 4.7: Breakdown of completed questionnaire 2

In the tables that follow, the results for each year and type of tutorial are separated. Table 4.8 gives the results for the academic year 1998/9, when thirty-three pairs of questionnaires were completed by a total of four tutors together with the students with whom they were working face-to-face. These results are separated from the data for the following two years because these were collected during the latter part of the year after the initial trials of the questionnaire were carried out and the modifications made to the questionnaire.

Tutor Question	Mean Tutor Score		Mean Student Score	Student Question
1) I was able to set clear aims for the Tutorial	4.52		4.67	The aims of the lesson were clear to me
1a) The aims of the Tutorial met the needs of the student	4.64		4.7	The aims of the lesson met my needs
2) I was able to adapt tasks set for the student in the light of the student's understanding and actions	4.97	Y	3.94	I was able to explain myself clearly to the tutor
3) I was able to describe required concepts to the student	4.70		4.52	The tutor was able to explain to me what I needed to know
3a) I was able to provide suitable examples for the student	4.85	Y	4.61	Examples given by the tutor were clear
4) I was able to provide suitable questions for the student	4.82	Y	4.42	I understood the tasks and the questions that the tutor wanted me to carry out
5) I was able to reflect on students' actions to provide feedback	4.64		4.76	I was able to think about where I had gone wrong
5a) I was able to give students feedback on tasks carried out by them	4.82	Y	4.52	The tutor was able to help me see the way forward
6) The questions I set for the student were challenging	4.85		4.67	The questions set by the tutor were clear and challenging
7) I was well prepared for the tutorial	4.45		4.45	The tutor was well organised
Note. A 'Y' in the middle column indicates that statistically at a 5% level there is a significant difference between the response of the tutor and student as measured by the Sign Test.				

Table 4.8: **Questionnaire 2-face-to-face tutorials (1998/9)**

Where a significant difference, as measured by the Sign Test has been identified the mean score for the tutor is in each case higher. This suggests that the tutor's perception of how well they are communicating with the student is better than the student's impression.

Table 4.9 collates the results for face-to-face tutorials over the two years 1999/2001.

Tutor Question	Mean Tutor Score		Mean Student Score	Student Question
1) I was able to set clear aims for the Tutorial	4.71		4.66	The aims of the lesson were clear to me
1a) The aims of the Tutorial met the needs of the student	4.63		4.60	The aims of the lesson met my needs
2) I was able to adapt tasks set for the student in the light of the students understanding and actions	4.66	Y	4.11	I was able to explain myself clearly to the tutor
3) I was able to describe required concepts to the student	4.54		4.63	The tutor was able to explain to me what I needed to know
3a) I was able to provide suitable examples for the student	4.74		4.54	Examples given by the tutor were clear
4) I was able to provide suitable questions for the student	4.66	Y	4.34	I understood the tasks and the questions that the tutor wanted me to carry out
5) I was able to reflect on students' actions to provide feedback	4.66		4.37	I was able to think about where I had gone wrong
5a) I was able to give students feedback on tasks carried out by them	4.86	Y	4.57	The tutor was able to help me see the way forward
6) The questions I set for the student were challenging	4.80	Y	4.46	The questions set by the tutor were clear and challenging
7) I was well prepared for the tutorial	4.51		4.54	The tutor was well organised
Note. A 'Y' in the middle column indicates that statistically at a 5% level there is a significant difference between the response of the tutor and student as measured by the Sign Test.				

Table 4.9: Questionnaire 2-face-to-face tutorials (1999/2001)

As with Table 4.8, questions 2, 4 and 5a show a significant difference using the Sign Test, between the response of the students and tutors, again with the tutors scoring the higher on average. The other significant difference was the perception by the students of the difficulty of the questions set by the tutor, the mean score for the students dropping from 4.67 to 4.46.

Table 4.10 shows the responses for participants using DVC over the period 1999/2001.

Tutor Question	Mean Score		Mean Score	Student Question
1) I was able to set clear aims for the Tutorial	4.58		4.67	The aims of the lesson were clear to me
1a) The aims of the Tutorial met the needs of the student	4.75		4.69	The aims of the lesson met my needs
2) I was able to adapt tasks set for the student in the light of the students understanding and actions	4.83	Y	4.47	I was able to explain myself clearly to the Tutor
3) I was able to describe required concepts to the student	4.56		4.78	The tutor was able to explain to me what I needed to Know
3a) I was able to provide suitable examples for the student	4.81		4.69	Examples given by the tutor were clear
4) I was able to provide suitable questions for the student	4.89	Y	4.44	I understood the tasks and the questions that the Tutor wanted me to carry out
5) I was able to reflect on students actions to provide feedback	4.92	Y	4.44	I was able to think about where I had gone wrong
5a) I was able to give students feedback on tasks carried out by them	4.97	Y	4.72	The tutor was able to help me see the way forward
6) The questions I set for the student were challenging	4.89	Y	4.47	The questions set by the tutor were clear and challenging
7) I was well prepared for the tutorial	4.28		4.50	The tutor was well organised
Note. A 'Y' in the middle column indicates that statistically at a 5% level there is a significant difference between the response of the tutor and student as measured by the Sign Test.				

Table 4.10: Questionnaire 2-DVC tutorials (1999/2001)

Those questions showing significant differences as measured by the Sign Test in the responses of the participants are the same as in the previous table with the exception of question 5, for which the difference is now significant. This would appear to be due to the tutor's scoring this activity higher than for face-to-face tutorials and suggests that they were more able to reflect on the actions of the students. Based on the comment of the second tutor in section 4.1.2 and the author's impressions of DVC, this is probably because the tutor can see a student's work more easily and can reflect on their actions as they develop.

Table 4.11 summarises the results of the previous three tables to identify where there are differences between face-to-face and DVC tutorials. Where this occurs it is indicated by 'Y'.

Question	Trial (face-to-face) 1998/9 (n = 33)			Face-to-face 1999/2001 (n = 34)			DVC 1999/2001 (n=36)		
	Tutor		Student	Tutor		Student	Tutor		Student
1	4.52		4.67	4.71		4.66	4.58		4.67
1a	4.64		4.7	4.63		4.60	4.75		4.69
2	4.97	Y	3.94	4.66	Y	4.11	4.83	Y	4.47
3	4.70		4.52	4.54		4.63	4.56		4.78
3a	4.85	Y	4.61	4.74		4.54	4.81		4.69
4	4.82	Y	4.42	4.66	Y	4.34	4.89	Y	4.44
5	4.64		4.76	4.66		4.37	4.92	Y	4.44
5a	4.82	Y	4.52	4.86	Y	4.57	4.97	Y	4.72
6	4.85		4.67	4.80	Y	4.46	4.89	Y	4.47
7	4.45		4.45	4.51		4.54	4.28		4.50

Note. A 'Y' in the middle column indicates that statistically at a 5% level there is a significant difference between the response of the tutor and student as measured by the Sign Test.

Table 4.11: Questionnaire 2 - summary of results

Where significant differences (as measured by the Sign Test) do occur, the higher mean score in each case is for the students using DVC. Whilst the reason for this is open to conjecture, it may indicate that DVC is at least as good a medium as face-to-face dialogue for mathematics tutorials. The implication of this is that students think they can communicate better with the tutor when using DVC. Consider for example question 2; the students' assessment of how they were able to explain themselves to the tutor; this scores much higher for DVC than face-to-face tutorials. The results for questions 4 and 5a again suggest better communication. The first of these suggests that the student was more likely to understand what was required of them and the second that the tutor was better able to explain concepts and techniques associated with performing tasks, when required to do so. The results for question 6, which are virtually identical for both types of tutorial, suggest that the standard of questions presented to both groups was consistent.

In each case where a significant difference occurs the mean score for tutors is higher than that for students. This suggests that the tutors' assessment of their skills is higher than that of the students. Considering the questions individually:

Questions 1 & 1a. Here some of the mean scores for the student exceed those of the tutor. The explanation for this may be that generally students do not have any preconceived ideas of what they expect to get out a tutorial and are happy to be led by the tutor.

Question 2. Whichever form of tutorial is used it appears that the tutors feel they are able to communicate better with the student than the student does with the tutor. Since the mean student mark for the students using DVC is higher than for face-to-face tutorials, this result suggests that the students felt they were able to communicate better using this medium.

Question 3a. This revealed a significant difference in the 1998/9 trials. However the author attaches no particular importance to this difference, as all the questionnaires completed in the trial were for face-to-face tutorials and adequate resources (in the form of the college's study modules, text books and past examination papers) were available for all tutors. The implication is that some tutors were failing to make best use of the resources that had been provided. What is seen as being important is that suitable examples could be provided using DVC.

Question 4. This suggests that tutors' may not make themselves as clear as they think when presenting a question to a student.

Question 5a. This suggests that the tutors' feedback may not be as clear as they think. Linked with question 4 this might suggest that tutors overestimate their communication skills.

Question 6. This reinforces the comment above for question 5a, that the tutors' feedback may not be as clear as they think.

Question 7. Here the tutors' average scores are equal to, or lower than, the students, suggesting that any shortcomings in the tutor's preparations are not evident to the students.

Key findings from Questionnaire 2

The key findings from these student/tutor questionnaires were:

i. The mean scores for both tutors and students show that many of the characteristics of the Conversational Framework had been met.

ii. There is no significant difference between the tutors' scores for face-to-face tutorials and DVC tutorials.

iii. There is no significant difference between the students' scores for face-to-face tutorials and DVC tutorials.

iv. Where a significant difference exists between the response of the tutor and student, the mean score of the tutors is higher than that of the students in each case.

To further compare the results of these questionnaires the mean scores were treated as being ratio scores rather than nominal ones. A Student *t* test on these scores, using a two-tailed test with unequal variance, produced the following results.

Results From		**Trials (face-to-face)**		**Face-to-face**		**DVC**	
		Tutor	Student	Tutor	Student	Tutor	Student
Trial	Tutor		0.041792	**0.440931**		**0.799529**	
	Student				**0.635675**		**0.48617**
Face-to-face	Tutor				0.007237	**0.365088**	
	Student						**0.140189**
DVC	Tutor						0.06186
	Student						

Table 4.12: Results of student t test applied to data from questionnaire 2

The results in Table 4.12 express the probability of there being no difference between the alternative approaches. For example, the probability that there is no difference between the tutor's results for face-to-face tutorials and the tutor's results for DVC is 0.365088. Hence at a 5% significance level there is no statistical difference between these two sets of results, and it can be concluded that there is no reason to assume that there is a difference between the two approaches. Comparing the other results in Table 4.12 at a 5% level there is no statistical, significant difference between the results for the three sets of data for the tutors or for the three different sets of student data (these are shown in bold type in Table 4.12). However a comparison of the data between the tutor and students shows that for the trials and face-to-face results there does exist a statistically significant difference, (probability less than 0.05) while for DVC the result shows there is no statistically significant different.

As face-to-face tutorials are by definition able to meet the characteristics of the Conversational Framework, and since there is no significant difference between the scores for the two methods, these findings suggest that DVC may equally well meet the characteristics of Laurillard's framework. With both forms of tutorial there may be a tendency for tutors to overestimate their communication skills.

4.3 Final questionnaire

A total of ten students completed the final questionnaire. In the first year thirteen students were sent questionnaires upon completion of their course and asked to complete them anonymously. As only six were returned, in the second year four students completed the questionnaire in the presence of the author. The ten students who completed this questionnaire were a subset of those who completed Questionnaire 1.

The author's comments on these questionnaires are included at the end of the following two sections:

i. The equipment -questions 1-9
ii. The tutorials -questions 10-18

Each student who completed the questionnaire is identified by a capital letter in brackets. This allowed the responses of each student to be tracked through the questionnaire.

4.3.1 The Equipment

This section of the questionnaire deals with the computer, its ancillary equipment and its location. The equipment comprised:

i. A PC with a 330MHz processor and 14-inch monitor.
ii. Windows 98 2nd edition.
iii. An Intel Proshare 500 DVC with version 3 software.
iv. A Genius 'Easypen' tablet.

The equipment was located within the area designated for mathematics learning support and partially separated by acoustic screens. This was intended to offer a degree of privacy to students using the DVC.

Tables 4.13 to 4.21 summarise the responses of the students to the questions relating to the equipment. Each student's comments have been classified as positive, negative or neutral as indicated in the right hand column of each table.

"How would you describe the quality of the audio connection?"		
Classification	No. of students	Free form comments
Very good	5	C) "Very clear" (+)
Good	3	G) " Sometimes I found the headset was hard to adjust to fit comfortably, but this was only a minor problem" (-)
OK	2	F) "Could hear myself echoing and a bit slow but generally alright" (-)
Not very good	0	
Poor	0	

Table 4.13: Q1- How would you describe the quality of the audio connection?

"How would you describe the quality of the video image?"		
Classification	No. of students	**Free form comments**
Very good	5	G) "The image clarity was improved during my period of maths support. Previous to this improvement I found the clarity more than satisfactory" (+)
Good	4	F) "Usually worked but was hilarious when the tutor's face froze and he looked like a frog" (+)
OK	1	D) "It took getting used to" (-)
Not very good	0	
Poor	0	

Table 4.14: Q2- How would you describe the quality of the video image?

"How would you describe using the pen and tablet?"		
Classification	No. of students	**Free form comments**
Very easy to use	2	
Easy to use	4	C) "At first slightly tricky" (-) J) "Maybe a bigger surface area for the tablet" (-)
Reasonably easy to use	4	B) "It takes a while to adjust to. And also sometimes the end bit gets stuck" (-) F) "My writing was too big and slanted but I got used to it. Doodling was very tempting though" (-) G) "I found using this system of pen & tablet strange at first, due to its small size. Once I got used to this process. no problems found" (o)
Not very easy to use	0	
Difficult to use	0	

Table 4.15: Q3- How would you describe using the pen and tablet?

"How would you describe making the connection with the tutor?"		
Classification	No. of students	Free form comments
Very easy	6	G) "No problems, I feel confident working with a computer as a medium for learning" (+)
Easy	3	I) "Although it didn't work sometimes" (-)
Reasonably easy	1	
Difficult	0	
Very difficult	0	

Table 4.16: Q4-- How would you describe making the connection with the tutor?

"Overall how easy did you find it to use the equipment?"		
Classification	No. of students	Free form comments
Very easy	6	
Easy	2	
Reasonably easy	2	F) "Quite fun actually, different" (+)
Difficult	0	
Very difficult	0	

Table 4.17: Q5- Overall how easy did you find it to use the equipment?

"How would you rate the location of the equipment?"		
Classification	No. of students	Free form comments
Very good	0	
Good	8	F) "Nice and tucked away" (+) G) "I liked the location and having a separate area dedicated to this form of study even though sometimes noise levels were slightly distracting due to overcrowding in the Student Support Centre" (+)
OK	2	
Not very good	0	
Poor	0	

Table 4.18: Q6- How would you rate the location of the equipment?

"Are there any ways in which you think the equipment or its location could be improved?"	
Free form comments	
A) "No"	(+)
B) "It could be moved to a more quiet environment"	(-)
C) "Maybe in a slightly more private position"	(-)
E) "There could be a little more space"	
F) "Not really – except the headpiece is a little big for my head, and I hope it doesn't give off radiation"	(-)
G) " Overall, no"	(+)
I) "It would have been better if the equipment were better quality"	(-)

Table 4.19: Q7- Are there any ways in which you think the equipment or its location could be improved?

"What did you like about using the equipment?"	
Free form comments	
)"It was a new experience in learning for me. I found I could grasp what I was doing easier than more conventional teaching methods. I would recommend this type of teaching."	(+)
C) "It was straight forward and modern. It's a good example of how technology can aid."	(+)
D) "No distraction it was situated in place where concentration wasn't broken"	(+)
E) "It was very adaptable"	(+)
F) "A new experience, colourful, saving trees"	(+)
G) " I liked using the equipment because of its interactive nature. Soon became used to this way of working"	(+)
H) " Much more relaxing"	(+)
I)" It was different. It wasn't something I hadn't used before; this is why I enjoyed it. Also the tutor was friendly."	(+)
J) "So easy to use and very quick"	(+)

Table 4.20: Q8- What did you like about using the equipment?

"What didn't you like about using the equipment?"	
B)" Sometimes it would be difficult to actually explain what areas you want to work in."	(-)
C) "Nothing"	(+)
E) "Sometimes connection problems occur"	(-)
F) " Slightly slow and I seemed to have a curse on it – I always made it go wrong"	(-)
G) " Sometimes the whiteboard would be lost, due to a period of talking – No writing (*screen saver*) hard to re-type password into computer. Therefore memory should last longer, before whiteboard is lost. Modify ability- or lack of it to save work on floppy disc" (*this is possible*)	(-)
H) " The headphones"	(-)
I) " I had a Monday morning slot, the equipment didn't always work in the beginning."	(-)
J) "Constant echo in my headset"	(-)

Table 4.21: Q 9- What didn't you like about using the equipment?

The students' responses to all of these questions about equipment were similar to the findings of the initial questionnaire, but gave more in depth answers, suggesting that students' views had not changed over time. Students still found:

i. The equipment simple to operate.

ii. Making the initial connections easy.

iii. The overall performance of the equipment satisfactory.

Technical problems

Those technical problems identified in the questionnaires were as follows:

i. Speakers/headset. Because the author found wearing a headset for extended periods uncomfortable and restricting, he tended to listen to the student via speakers, which caused an echo in the headset of the student. The availability of cordless headsets now means this problem can be eliminated.

ii. The pen. This was a problematic area for some students and has now been replaced by a slightly larger tool with software, which makes it possible to write into any application. This means that past examination papers, which are available in PDF format from the Internet, can be worked on directly by the student and tutor.

iii. Connectivity. These difficulties were overcome as soon as ISDN connections were being used rather than the Local Area Network at the college.

All the problems mentioned above were resolved during the course of the research.

Contradictory students' responses

The responses to questions 7, 8 and 9, which asked about the positioning of the DVC and the equipment, showed opposing opinions to issues such as the location of the equipment. While several students suggested the location might be improved by sighting the equipment in a quieter location, another found it quite relaxing where it was. Ideally the computer would have been located somewhere quieter, but its location was dictated to a large extent by available space and resources. The position of the computer was thought by most students to be good and approximates to the recommendation of the SAVIE report (1999).

Possible improvements

A larger screen, or possibly dual screens, may have helped overcome the issues of shared space and would, for example have allowed the whiteboard and a Mathcad file to be seen simultaneously. The Mathcad software package was found to be particularly useful for producing graphs because of the speed and ease with which they can be drawn. A further advantage found when using this software was the ability to zoom onto a particular section of a graph or modify the graph, which was particularly useful when trying to correct a student's misconceptions, especially in the area of function transformation. The various stages of the transformation from a known curve (e.g. $\sin\theta$) to a curve such as $2\sin(3\theta)+1$ can easily be built up in stages using Mathcad, and at the same time allow students to keep sight of their original answers.

Student response, or rather the lack of it, to the quality of the video image was thought by the author to be of considerable significance. The quality of the video image was improved once an updated version of the software was available but even then the quality was not good. Despite this, no student commented on it. In line with other research, Whittaker (1995), Hearnshaw (1997) and Reeves and Nass (1996), this suggests that the quality of the video image is not important in terms of the learning experience, but rather that the audio quality is of paramount importance. It should be noted that the video image was only used at the beginning for purposes of greeting and discussing the objectives for the tutorial and at the end of a tutorial to finalise the session and discuss arrangements for the next tutorial. During the bulk of the tutorial (on average at least 90% of the time) both the student and tutor were viewing the whiteboard. Information conveyed using the video was minimal and was only rarely used, for example, if a student was unable to adequately describe a diagram they could hold it in front of the camera.

The results suggest that there are no technical issues that impinge on the learning experience of the students, thus making DVC comparable to face-to-face tutorials in terms of the mechanics of the process as opposed to the academic content.

4.3.2 The tutorials

This section of the final questionnaire sought to elicit from the students any differences they perceived between the learning experience using DVC and that of face-to-face support. Each student's comments have been classified as positive, negative or neutral as indicated in the right hand column of each table.

"Please list what you see as the differences between DVC tutorials and face-to-face tutorials"	
Free form comments	
C) "DVC tutorials are at least more convenient for one person. Slightly more formal"	(+)
D) "DVC meant didn't need a pen or paper. With DVC you don't need to sit too close to the lecturer, which might make student feel uncomfortable. DVC made it fun while learning"	(o) (+) (+)
E) "The speed, viewing, timing, graphical representation"	(o)
F) "Less personal, Sometimes more fun though, Saving trees (thumbs up)"	(-) (+) (+)
G) " I preferred DVC tutorials compared to face-to-face, less intimidating. Able to focus on information given rather than who's providing the information"	(+) (+)
H) " DVC harder to explain some things"	(-)
I)" I didn't feel there are many differences apart from the obvious ones i.e. the tutor wasn't sitting next to me."	(o)
J) " More interesting"	(+)

Table 4.22: Q10- Please list what you see as the differences between DVC tutorials and face-to-face tutorials.

Students' comparisons of DVC and face-to-face tutorials

Table 4.22 gives the responses to question 10. Three students mention the relative physical location of the tutor, the inference from their comments being that they found it less intimidating when the tutor was in a remote location. It is thought that the physical location of the tutor is a major contributing factor to the students' responses to question 13. These comments are consistent with a number of those made in the initial questionnaire.

One student commented that DVC tutorials were more formal than face-to-face; on the other hand some suggested they were more interesting/fun.

"Do you think there is any significant difference between using a whiteboard and paper?"		
Classification	**No. of students**	**Free form comments**
Yes	6	B) Takes a while to get used to. But when you have got used to it, it is fine (o) D) "Notes cannot be taken home. So the student has to write twice once on board and again on paper" (-) F) " Saving trees and simply getting used to it." (o) G) " Whiteboard you are able to erase your working a lot more easily-which in my case was very good. Also used paper to make my own notes" (+) J) " Not as boring" (+)
No	4	C) " It's just old fashioned" (+)

Table 4.23: Q11- Do you think there is any significant difference between using a whiteboard and paper?

Table 4.23 lists the responses to question 11. One student commented on not being able to take their work home a problem that could be overcome by either e-mailing the whiteboard file to the student, providing a printer so that the student can print off the whiteboard or the student saving the whiteboard onto a diskette so that they can review the tutorial in their own time.

"How does using a whiteboard compare to using paper?"			
Classification	**No. Of students**	**Free form comments**	
Much better	1	C) " It's easier to store work on a disk"	(+)
Better	5	B) Saves trees E) "Mistakes are easily highlighted using a whiteboard" G) " Once I was used to using the whiteboard, I preferred using this tool" I)" It was easy to use, easy to rub out mistakes etc."	(+) (+) (+) (+)
About the same	2		
Not as good	2	D) " The electronic pen is more difficult to use" F) "But only because I'm not quite used to it"	(-) (o)
Much worse	0		

Table 4.24: Q12- How does using a whiteboard compare to using paper?

Table 4.24 lists the responses to question 12. The majority of students preferred using a whiteboard; two of these mentioned the fact that corrections were easier to make. Identified advantages of the whiteboard over paper are:

i. Both participants have a clear view of work in progress.

ii. Corrections can be made more easily.

iii. Work can be highlighted.

iv. As Ruthven and Hennessy (2002) suggested, being able to correct errors easily is seen as a distinct advantage by students.

"Overall how would you describe a tutorial using the computer compared to face-to-face?"			
Classification	**Number Of students**	**Free form comments**	
Much more intense	0		
More intense	0		
About the same	4		
Not as intense	3	F) " Because the teacher can't physically force you to work (ha ha) and less eye contact"	(o) (-)
Much less intense	3	G) " Much less intense, in a good way. Able to focus on learning instead of worrying about having face-to-face	(−)

		interaction. I found the distance created enabled a lot more intense learning experience" J) " More relaxing" (+)

Table 4.25: Q13- Overall how would you describe a tutorial using the computer compared to face-to-face?

Table 4.25 lists the responses, which the author considers to be key outcomes from these questionnaires. All the students concluded that DVC offered a learning experience that was equally or less intense than a face-to-face tutorial. This is at variance with the perception of the tutors participating in this research and other researchers e.g. Jennings *et al.* (1998). The impression of all tutors was that the tutorials were much more intensive for both participants. A DVC tutorial is undoubtedly more demanding and tiring for the tutor, as a consequence of having to both conduct the tutorial and manage the software, but in contrast the students reported that they found it less intense.

One explanation for students finding it less intense may lie in a consideration of each student's 'personal space'. Personal space is defined by Sommer (1969) is "*an area with invisible boundaries, surrounding a person's body into which intruders may not come*". Using Hall's (1966) classification of personal space, face-to-face tutorials are conducted either in the Intimate zone (0-1.5 feet), or the Personal zone (1.5 – 4 feet). Research conducted into the effect of working in close proximity to a student has had contradictory results (Greenhead, 2004). One explanation of the effect from the intrusion of personal space given by Greenhead (2004) is:

> *Stress and arousal explanations. This interpretation assumes that we maintain personal space to avoid various stressors associated with too close a proximity. ... When this occurs we attempt to understand why we are aroused, perhaps because of love or fear, and the type of explanation we come up with determines how we respond to inadequate personal space.*

For some students the physical location of the tutor (see responses to Q10) in a face-to-face tutorial may be intimidating. Students perceive the tutor to be less intimidating when he is not located in close proximity to them, which in turn leads to their perception of the tutorial being less intense.

Other researchers such as Hearnshaw (1997), have identified DVC tutorials as being more focused and intense despite the implications of close proximity being eliminated. This study suggests that from the students' perspective the tutorials are at least less intensive, although this does not prevent them from being more focused. In fact it may well be that because students feel the tutorial is less intense, they were generally less distracted and hence they were able to focus more on the task at hand. This is certainly the impression gained by the author.

"Please suggest ways in which you think DVC tutorials could be improved"	
Free form comments	
G) " Overall apart from a couple of technical modifications: 1) Saving work covered 2) Whiteboard memory when not in use The DVC tutorial should become more commonplace. More information available so more people could benefit as I have"	(+) (+)

Table 4.26: Q14- Please suggest ways in which you think DVC tutorials could be improved.

Table 4.26 lists the responses to question 14. The most significant issue seemed to be keeping a record of the work done during the session for the students to refer to, a point that also emerged in the students' responses to question 11. The possibility of keeping a record on a disc or printing out a copy of the whiteboards was discussed earlier.

"How much do you think you learnt in an average DVC tutorial compared with a face-to-face one?"			
Classification	**No. of students**	**Free form comments**	
Much less			
Not as much	2	D) "I had more lectures face to face than on DVC	(o)
About the same	4	F) "I think the teacher has more power face-to-face sometimes and it might be slightly easier to explain but generally fun and good. A lot more than in the maths workshop"	(o) (-) (+)
More	1	I) " I gained IT skills"	(+)
Much more	3	G) " I enjoyed the tutor's approach – looking at simplifying areas of difficulty. To enable learning without feeling overwhelmed with unnecessary information" J) " It really helped me in my maths to a point where I enjoy maths"	(+) (+)

Table 4.27: Q15- How much do you think you learnt in an average DVC tutorial compared with a face-to-face one?

Table 4.27 lists the responses to question 15. Here the students were divided on how much they thought they had learnt. The results achieved by these students in their GCSE's suggest that they learnt as much using the medium of DVC as they did from face-to-face tutorials. This is supported by the fact that all students receiving learning support through DVC achieved a grade B or C in their examination (see Chapter 5 for a statistical analysis of their performance).

"What didn't you like about DVC tutorials"	
Free form comments	
C) " Nothing"	(+)
E) " Software problems"	(-)
F) "Sometimes if I'm <u>really</u> struggling it's easier face-to-face to explain in lots of detail. But otherwise it's just as good"	(0)
I)" There was an echo when you speak, and I don't like the sound of my voice."	(-)
J) "My early morning slot"	(0)

Table 4.28: Q16- What didn't you like about DVC tutorials?

Table 4.28 lists the responses to question 16. No serious shortcomings or dislikes were apparent from the students' responses. The issues that were raised are considered to be minor and were resolved at an early stage. The student who disliked his early morning slot continued at that time, as it was the only time mutually acceptable to both the student and tutor.

"Which type of tutorial do you prefer?"			
Classification	**Number of students**	**Free form comments**	
Face-to-face	1		
DVC	8	B) "Easier to pick up"	(+)
		C) "You can run away"	(0)
		D) " More fun, more secluded, better concentration"	(+)
		E) " Mistakes can be highlighted easier"	(+)
		F) "Either- they both have good and bad points. I wouldn't like it all the time though- in all my lessons, because humanity would lose their social skills"	(0)
		G) "I have experienced both forms to help with my maths aspect of my course. Found face-to-face very hard to follow. Also taught in small group-so learning dependent on other students' understanding – not always matched."	(+)
		I)" I liked using the equipment"	(+)
		J) " My maths grade has improved"	(+)

Table 4.29: Q17-Which types of tutorial do you prefer?

Table 4.29 shows that whilst students overwhelmingly preferred DVC, this may in part be due to the Hawthorne effect. The students' preference for DVC is thought to be due in a large part to students finding it a more relaxed experience and in their eyes a less intense environment within which to work. There seems little doubt from the students' responses that they found the DVC environment to be one that was conducive to effective working. This is seen as being mainly a consequence of the location of the tutor, fewer distractions and a more focused working environment.

Student **C's** comment is thought to refer to the fact that no physical restraint can be exercised by a tutor when working with DVC. The significance of this would be purely conjecture.

"Any other comments you would like to make"	
Free form comments	
B) "I would recommend this type of learning. Even though some people may find it more effective than others "	(+)
G) " Just to say DVC method has personally been an excellent medium for understanding an area of study that used to fill me with dread and fear. I enjoyed my extra tuition and am very glad of the experience offered me, with support and encouragement I reached my goal."	(+)
J) "Keep up the good work"	(+)

Table 4.30: Q18- Any other comments you would like to make?

Table 4.30 lists the responses to open question 18. Although only three comments were made they were all positive. Student **B's** comment suggests that she thought that DVC would work better with some students than others, which seems reasonable as some students definitely do not like computers.

The key findings from the final questionnaire were:

i. Students' opinion of DVC did not appear to have changed in any great measure from their initial impressions.

ii. The students saw the remote location of the tutor during a DVC tutorial as an advantage since they found this less intimidating than sitting next to the tutor.

iii. Students reportedly found DVC tutorials less intensive.

iv. With all but one exception, students preferred DVC.

v. The whiteboard has distinct advantages over using paper.

vi. The audio quality is of key importance to the effectiveness of learning.

vii. The video quality is not as significant as the audio quality.

viii. DVC can satisfactorily fulfil all the requirements of a medium necessary to satisfy the characteristics of Laurillard's Conversational Framework.

4.4 Interviews

The aim of the interviews was to gain more insight into some of the responses that had been made on the final questionnaires and therefore add further insight to the author's understanding of the students' opinions of DVC. Three students who had completed the Final Questionnaire were interviewed approximately three months after their examination. The students knew the grade they had obtained in their re-sit examinations, two had grade C, and the other a grade B. The three students were chosen for the following reasons:

i. They had all received learning support using both DVC and face-to-face tutorials and would thus be able to make a comparison between the two methods.

ii. The main courses of study being undertaken by the three students were very diverse. One was doing a diploma in IT studies, the second 'A' levels in arts based subjects and the third was doing a re-sit GCSE package having dropped out of school and failed to sit his GCSE's.

iii. They had more experience of DVC than any of the other students and would be best placed to evaluate it.

iv. Both genders were represented.

The interviews were semi-structured with the student's Final Questionnaire being used as a basis for the questions, with supplementary questions being asked as a response to the answers given by the student. The students were actively encouraged to elaborate on their answers during the interviews.

Interview 1

Student E had received two hours learning support each week, one hour using DVC and one hour face-to-face. He was a student doing a GNVQ in IT studies and was partially sighted. He was considered to be in a good position to compare the two forms of tutorial albeit subjectively. The interview was conducted using DVC, recorded and transcribed. The following salient points arose from that interview:

Location & set up of the equipment

Student E considered the equipment to be well located in the corner of the area designated for mathematics support, which offered a degree of privacy due to the provision of an acoustic screen. This location had the advantage that there were fewer distractions than in the main learning support area and this student was happy to work in an environment where he had people around him (except when doing examinations).

The Equipment

The student's comments on the equipment were:

i. He found using the equipment an interesting addition to his IT course.

ii. DVC eliminated the need for paper, "I *think it's easier to work with than writing it on loads of bits of paper, you don't lose any of your work.*"

iii. He thought the use of a larger monitor (15") would be better; this was due to his eyesight rather than a shortcoming of the equipment.

The tutorials

He thought working through examination papers was easier face-to-face because of the difficulty of replicating questions in the computer. In some instances, because of his eyesight, he found it difficult to reproduce diagrams from the examination papers on the whiteboard. For learning new topics he preferred DVC because he found it quicker and easier to pick up the ideas involved. This is illustrated in the following extract from the transcript of the interview.

Tutor *"You had sessions with me both face-to-face and using DVC. What do you see as being the main differences between sitting next to a tutor and doing it using DVC?"*

Student *"Face to face is better for doing examination papers; I preferred learning new things using this(DVC)".*

Tutor *"Why"?*

Student *"I found it easier and quicker to pick up, definitely quicker".*

Tutor "Do you have any idea why?"

Student

> *I think it's because when you are working, say when you are doing a bit of work here. You are showing how to do it, for example that long division. Now when I was doing that here I have to write it in front of me and then give it to you and you look at it. Whereas when you are using this (DVC) you can see what I'm doing as I'm doing it and I can see what you are doing as you were doing it which I found much easier. That's probably why I preferred learning new things because I could see what you were doing without having to watch you write it and then pass it to me.... You can correct me before I went too far.*

The student was of the opinion that the quicker the tutor gave feedback the easier and quicker he was able to learn, since he thought that less of his time was being wasted making errors. By this he meant that if he was allowed to continue with a problem beyond the point where he had made a mistake, then this was time wasted. A similar environment could be created with a face-to-face tutorial if both parties worked on a conventional whiteboard together.

Student E identified the following features of the whiteboard that he saw as being an advantage over using paper:

i. All work done during the tutorial can be saved.

ii. Alterations can be easily made.

iii. Clear and accurate diagrams can be quickly produced.

iv. The highlight feature is very useful, especially with things such as probability trees.

v. Being able to change the colour of pen easily.

Student E thought DVC tutorials could be improved by:

i. The use of more pre-prepared, electronic worksheets.

ii. Having examination papers electronically stored.

The student felt that he was learning more and that there was less pressure using DVC.

Tutor *"Why do you think that is?"*

Student *"When you are doing it face-to-face you have the tutor sitting there looking over* *your shoulder and I find that more intimidating, even though you were watching me writing it on the screen I don't know that. I don't know that you are watching it."*

Tutor "*You do, but you don't actually think about it do you?*"

Student "*No, whereas when you are writing it you know someone is there watching you*"

When pressed further on this issue he expressed the view that DVC is less intense because "*the tutor is not sitting next to you.*"

Interview 2

Student F spent two years working for her re-sit of GCSE mathematics. In her second year, as a consequence of internal restructuring with respect to how GCSE mathematics would be delivered, it was not possible for her to attend any classes and she received two hours each week of learning support.

The main subjects she had studied for 'A' level were Dance, Drama and Psychology and she went on to study Dance at university. She recognised that to get into the university of her choice she would need to have a grade C for GCSE mathematics and needed to study the subject. She could also be described as 'maths phobic'.

Using the same format as for the previous interview, this interview began with a consideration of the equipment. The following section of transcript covers the student's assessment of the quality of the audio connection.

Student " *Not very good, it went wrong sometimes and sometimes it felt like it was resonating and I could hear myself and sometimes it would be quite slow, so you finish up talking over each other.*"

Tutor " *Do you have any comments on the video quality?*"

Student " *No not really, usually it was pretty good.*"

Asked about the location of the equipment she commented on the high level of background noise in the drop-in-centre on occasions. Asked what she liked about using the equipment.

Student " *I found it easier to understand visually, because I think my brain works better with lots of pictures and things rather than sound experiences.*"

Tutor " *What didn't you like about using the equipment?*"

Student "*It can be impersonal.*"

Tutor *"What do you mean by that?"*

Student

> *You are not actually with someone, it was quite good fun at first taking the 'mick' out of each other, but with another student you may not be able to get as much out of them as you would if you were there with them. You don't get a sense of what it is like to know the person as much, so if the whole world was taken over by people delivering lectures over, like in the future, people might not understand how to socially interact with other people and how to interact and how to use body language like in the very distant future.*

Tutor *"So the fact that it is slightly impersonal you see as being a disadvantage."*

Student *"Well yes, I enjoyed my tutorials but for some people it is nice to have the contact like seeing someone."*

The long-term social effect of the use of this sort of technology emerges as the biggest issue for student **F**. She was the one student who would not state whether she preferred DVC or face-to-face tutorials. This student recognised that DVC had worked well for her but was at the same time concerned about the social effects of the wider application of such technologies.

Tutor *" Why do you think the tutorials are not as intense?"*

Student *" Because you can get distracted more easily than when a tutor is with you... its easier for me to drift off."*

Tutor *"Do you think you did more or less work than you would have expected to do?"*

Student *"I don't know I would find it easier to answer that question on a different subject because maths always seems like loads of work to me, but I can't tell really. Probably about the same although when we were doing that algebra we did seem to churn out more."*

When pressed on the issue of which form of tutorial she preferred

Student *"Neither because I can't decide. They are both fine for different reasons."*

Tutor *"Can you identify the differences?"*

Student *"I suppose you sit down and you are fully staring at it (DVC) so your concentration can be improved by that..... and you are completely focused on it and the fact that you are not sat with other people as well so you can't talk to any one.*

If I was given the choice as to which form of tutorial to use now I would say I don't mind"

Tutor *"Do you feel more confident working with computers now?"*

Student *"Yes."*

The impression gained by the author during this interview was that the student was unable to identify any real differences between the two types of tutorials, but that she believed that face-to-face ought to be better.

Interview 3

Student J can best be described as the antithesis of student F. He was sitting GCSE for the first time having been withdrawn from his previous school. After obtaining a grade B for his GCSE he went onto study for 'A' level mathematics during which he continued to receive learning support. The interview with him was conducted using the DVC with handwritten notes being made at the time.

With respect to the equipment he thought this would be improved with a bigger surface area on the tablet and he complained about the echo in the headset but noted that this was not present when the tutor was using a headset. Commenting on the tutorials he said:

i. *"They are different. I feel I participate more."*

ii. *"Working with paper is quicker."* When asked why he said *"It is quicker to write on paper than the whiteboard although I prefer the whiteboard. The whiteboard is slower because you have to look at the screen not the paper when you write."*

What he had identified was that a different motor/eye coordination skill had to be developed. This was an interesting observation on his part; it undoubtedly takes some time to acquire the new skill required to write quickly using a whiteboard.

iii. Like the other students, he found DVC more relaxing and less intensive. *"I have learning support face-to-face with other tutors but I prefer video conferencing because my personal space is not invaded."*

iv. *"Having the tuition has made me more enthusiastic about doing maths."*

This student was very enthusiastic about using DVC. This may in part be due to his previous experiences, but there is no doubt that he made good progress academically while working with DVC. Whether there are any grounds for supposing that it has helped improve his self-confidence, is difficult to judge. Having on occasions worked on a face-to-face basis with the student the author is convinced that he learns more when using DVC. On his questionnaire when asked about how much he had learnt, he wrote *" much, much more"*.

4.6 Conclusions

To conclude, the results from the interviews and questionnaires were consistent with the results highlighting common themes. There was no evidence of the students having modified their opinions in the three-month period between the questionnaires and interviews.

In terms of the main research questions, the results from the questionnaires identify that the students found that DVC is a different experience from face-to-face tutorials. The results do not provide any evidence that there is a difference in terms of learning outcomes, there is however a difference in the learning experience of the students.

This is the first research that the author is aware of into the effectiveness of DVC when used in a one-to-one situation for mathematics tuition. The results from this research show that students overwhelmingly enjoy it and felt the medium was as good as face-to-face tutorials, with no detrimental effects in terms of the learning outcomes.

The following summary brings together common themes from the questionnaires and interviews.

Equipment and its location

i. The computer could have been located in a quieter setting.

ii. A larger screen would allow more of the whiteboard to be seen and would be helpful to any student or tutor with impaired sight.

iii. The tutor using a headset, rather than speakers can eliminate echo in the students' headset.

iv. Provision of a printer at the student computer would allow students to take a hard copy of their work if they wanted it.

v. Students do not find the technology threatening.

vi. The quality of video image does not form an important component of the DVC; rather the quality of the audio and shared images such as the whiteboard must be maintained, even if this is at the expense of the video image.

The Tutorials

The results from question 17 of the Final Questionnaire suggest that students prefer tutorials using DVC. The following points may explain this conclusion:

i. The fact that both participants have a clear view of the whiteboard at all times makes it easier for both participants to see the construction of an argument as it progresses. This enables the tutor, should they choose to do so, to provide instantaneous feedback when the student makes an error. This would not be possible if the tutor was sitting next to the student.

ii. Errors can easily be corrected.

iii. The additional features such as highlighting on the whiteboard make it possible for the tutor to provide non-verbal feedback at the same time as the student is working.

iv. Students find DVC less intense, probably due to the remote location of the tutor. They do not think that someone is "looking over their shoulder" all the time. Some students clearly find working in close proximity to a tutor intimidating.

v. The environment of DVC leads to a more focused working atmosphere with fewer distractions for the student.

The results from the questionnaires do not provide any hard evidence to suggest whether DVC is better, worse or the same as face-to-face tutorials with regards to learning outcomes. They do however, suggest that DVC provides a different learning experience (also noted by Jennings (1998). In particular one in which students feel more relaxed, whilst at the same time being one in which the tutor can provide more support through the feedback.

New findings

The following new findings on DVC emerge from the questionnaires and interviews.

i. DVC is an effective medium to provide support for mathematics students. This is based on the results of Questionnaire 2 that show that the characteristics of the Conversational Framework are being met and the fact that 80% of the students in the Final Questionnaire thought that they had learnt as much or more in the DVC tutorials compared with face-to-face tutorials.

ii. The whiteboard makes the tutorials more interactive and dynamic as it offers the opportunity to integrate other software packages into the tutorial. This facility was used where appropriate and was found to be particularly effective when discussing graphs.

Findings supporting other research

The results of these questionnaires support earlier research findings, specifically:

i. Whittaker (1995). Audio quality is far more important than the video.

ii. UCL (2002). The interactivity of the system that allows for more participation by the student. This is seen as having a pedagogical value, an example of this is students also having access to the whiteboard traditionally in the teacher's domain.

iii. Jennings *et al.*,(1998). DVC provides a different experience to face-to-face tutorials.

iv. Hearnshaw,(1997). Tutorials are more focused.

v. Hearnshaw,(1997) & Mayes,(2002) There are pedagogical benefits to be derived from using DVC, for example the students are more focused. Also the lack of 'telepresence' (looking at a video image of the other participant) may help to reduce the intensity of the tutorial and reduce the mental effort directed towards interpreting the video image, which is generally not subject specific.

Chapter 5 Results from statistical analysis

5.0 Introduction

This chapter starts by considering the type of statistical data collected during the course of the study and then goes on to look at the results obtained from the analysis of this data.

Data were collected, over a three-year period, from all the students re-sitting their GCSE mathematics at Exeter College. During this period the college had no effective central database for student records (a situation that has now been corrected), which caused a few problems. Fairly wide ranges of data were collected during the first year of the study with the intention being to cover all the factors that might be significant in predicting a student's performance. An initial analysis on the data for the first cohort of students in the study allowed the author to refine the list of factors that were included in the study in the later years.

The chapter then moves on to describe how statistical techniques were used to build a model that could be used to predict the final GCSE result of a student, given a set of information about the individual student. Both correlation and multiple regression techniques were used to identify the factors that were important predictors of the GCSE grade and to form a model that could be used to make predictions.

5.1 Statistical data collected

Data were collected from a number of sources within the college ranging from formal examination results to more informal data held by individual tutors. The types of data to be collected were selected because it was considered that they might influence the students' final GCSE grades in some way. The sources of statistical data used were:

i. Records from the Mathematics Department.

ii. Individual tutors' records.

iii. The college examination office.

iv. Data collected by the author.

Cohorts included in the study

Table 5.1 below gives a breakdown of the cohorts included in the study. Each cohort comprised of all the Exeter College students re-sitting GCSE mathematics, who had registered with the Mathematics Department during the first two weeks of the academic year. The number of students starting the course decreased after the second year, as did the proportion of students sitting the examination, which was as a consequence of policy changes at the college. One example of this was that students failing to achieve a grade D or E at school were put onto a pre-GCSE course for one year before being allowed to join a GCSE group. The table below also gives a number to each cohort of students: these cohort numbers were used to identify each of the three cohorts involved in the study.

Academic year	Cohort number	No. of students starting course	No. of students sitting GCSE	Grades in GCSE examination at Exeter College				
				B	C	D	E	X
1998/1999	1	310	120	8	53	40	15	4
1999/2000	2	297	82	14	35	24	6	3
2000/2001	3	261	73	8	37	26	2	0

Table 5.1: Students in cohorts and their GCSE re-sit results

Student retention rates

Figure 5.1 below shows the retention rates for students for the period of the research, the figures in brackets for each category show the number of students completing their GCSE mathematics. The data for '*All students*' and '*All learning support students*' are for the academic year 1999/2000 and the figure for '*Students supported with DVC*' is the combined figure for the academic years 2000/1 and 2001/2. The improvement in retention rate amongst students receiving learning support is in line with other research (Basic Skills Agency, 1997). The very high retention rate amongst students receiving support using DVC may be significant, possibly due to the realisation by students that this formed part of a research project and their wish to cooperate. It must also be recognised that the students using DVC were not a truly random sample of the students receiving support (see section 3.1.3). However, the results of the questionnaires (section 4.1) show that students overwhelmingly preferred DVC to face-to-face tutorials. Although non of the students who completed Questionnaire 3 or were interviewed (see Chapter 4), made any reference to DVC contributing to their having completed the course, it is never the less reasonable to surmise that the experience of using DVC did contribute to the retention of students.

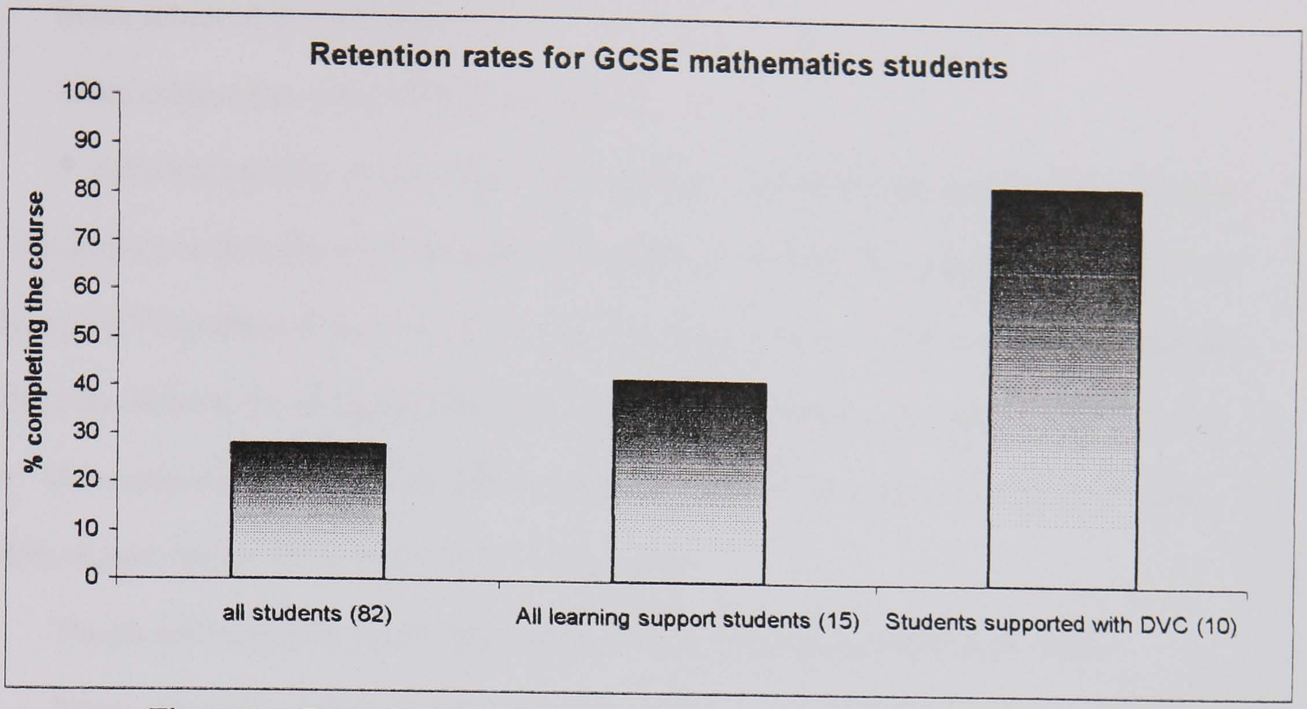


Figure 5.1: Retention rates amongst students re-sitting GCSE mathematics

Building a model

The statistical analysis conducted as part of this research focused on building a model capable of predicting the outcome of students re-sitting their GCSE's. By using this model it was hoped that a comparison could be made between the actual grade obtained by a student and that predicted by the model for those students receiving learning support. This in turn would give a measure of the 'value added' from the learning support, in particular the DVC support.

The initial step in the process was to collect data during the first academic year, for the students in cohort 1, covering as many of the parameters as possible that were thought might have an affect on the learning outcome. Next, a correlation analysis would be applied between these data and the mock examination results to see which if any of the parameters were significant. The parameters chosen were decided after discussion with staff at the college, in particular Dr Barbara Janssen the Learning Support Co-ordinator. The parameters used for the first years data collection from cohort 1 were:

i. Last school attended.

ii. Grade obtained when the student previously sat GCSE mathematics.

iii. The level of GCSE mathematics taken previously i.e. Foundation, Intermediate or Higher.

iv. Points on entry to the college.

v. Score achieved in first mathematics assessment at Exeter College.

vi. Hours spent in the mathematics workshop or classes during the period of study.

vii. Score achieved in the attitude test.

viii. Score achieved in mock GCSE examination.

A statistical analysis of the cohort 1 data collected for the parameters above was carried out. Discussions with Professor D Burghes (University of Exeter), who had done some work on predicting GCSE grades obtained at school, also took place. Based on the results of the analysis and these discussions, the changes listed below were made to the data collected for the next two years. The changes were made in an effort to improve the regression model for predicting the outcome of students re-sitting their GCSE mathematics.

The parameters listed below were discarded in years two and three of the study.

i. **Points on entry to the college**. The author deemed the points awarded on completion of the newly introduced GNVQ to be disproportionately high and not a true indicator of a student's mathematical ability. The correlation between points on entry and the result of a student's first assessment at the college yielded a coefficient of 0.13 for the cohort 1 students. The low correlation coefficient confirmed the view that this was not a useful factor to take into account.

ii. **Score in first college assessment**. This was replaced with two tests, numeracy and potential, based on a shortened version of the tests developed by the MEP project at the University of Exeter. It was felt that these two tests, which had been extensively trialled with school pupils, would provide more reliable information about a student's level of mathematical development.

The parameters listed below were added after the first year of the study.

i. Gender.

ii. Potential test.

iii. Numeracy test.

The effect of these changes was that the data collected during the first year was of little subsequent use and could not be included in the regression analysis. Having determined the parameters for which data were to be collected for the second and subsequent years multiple linear regression was applied to these statistics (see section 3.3.2 for details).

Table 5.2 summarises the data collected on students during the course of the second and third years of data collection.

Description of explanatory variable	Type of data
Gender	Nominal
Score in Numeracy test	Interval
Score in Potential test	Interval
Grade obtained in GCSE mathematics last time	Categorical
Level GCSE mathematics studied at previously	Nominal
Last school attended	Nominal
Attitude test	Ordinal
Hours spent in workshop/lessons	Ratio
Hours of learning support received	Ratio
Score in Mock Examination	Interval

Table 5.2: Data collected on students.

In order that as much of the data as possible could be used in multiple linear regression analysis, the following transformations were applied to the data:

Gender

The average mark obtained in the mock examination, (for which a previous GCSE examination paper was used) was, 41% for girls (sample size forty-three) compared with an average mark of 43% for boys (sample size twenty-eight). Comparing the results for the potential test, (girls 10.8 and boys 11.1) with the numeracy test (girls 15.8 and boys 17.0) revealed a similar trend with the boys performing slightly better than the girls (see section 3.3.2 for details of potential and numeracy test). These results were at variance with the results of the MEP project (Burghes, 2000), which predict that on average girls score higher than boys on both the potential and numeracy test. These results are also at variance with the national statistics for England and Wales where, for the academic year 2001/02, girls on average scored 9% higher over all subjects and 1% higher in mathematics (BBC, 2002). The difference between the scores for boys and girls was not considered to be significant and gender was not considered in the regression analysis.

Examination level

This was the level at which the GCSE mathematics examination was last taken, a factor determined by the level of the syllabus previously studied. The students in this study had taken the examination at either Foundation or Intermediate level. Students who had studied at Foundation level were clearly at a disadvantage, as this syllabus did not cover all the curriculum requirements needed for the Intermediate course. All the students needed to take the Intermediate examination in order to be able to obtain a grade C.

The average result obtained in the mock examination for students who had previously studied at Foundation level was 32.75% (twelve students), compared to 41.45% (fifty-three students) for those who had studied at Intermediate level.

Within each group there was little difference between the scores for those who achieved a grade D and those who achieved a grade E when they previously sat the examination. This difference, less than 0.5%, was ignored for purposes of the analysis. In order to compensate for the students who had previously sat GCSE mathematics at Foundation level a factor was introduced into the analysis to produce a level playing field for all students. A factor of 1.25 was used for those who had taken the GCSE at Intermediate level and a factor of 1 for those who had taken it at Foundation level. The factor of 1.25 is an approximation (to 2dp) of the result of dividing the average score of students who previously sat GCSE mathematics at Intermediate level by the score for those who were previously examined at Foundation level.

Attitude test

Table 5.3 shows the marking scheme applied to a student's responses to the test.

Response on Likert scale	Positive statement about mathematics	Negative statement about mathematics
Strongly agree	2	-2
Agree	1	-1
Not sure	0	0
Disagree	-1	1
Strongly Disagree	-2	2

Table 5.3: Marking scheme for attitude test

Table 5.4 below shows the mean scores for each of the statements in the attitude test. The two groups of students were:

i. The students described as "*All students*". This sample group was used during the development of the test and included: students studying for 'A' level mathematics, GCSE mathematics, Key Skills mathematics and some doing vocational courses that required no mathematics.

ii. A random sample of 20 GCSE students. The sample was chosen using a systematic sampling method from the accumulated tests.

	Statement	Mean score	
		All students	GCSE Retake Students
1	I enjoy maths	-0.6	0.4
2	A good grade at GCSE maths will help me to get a good job	0.8	1.6
3	Universities should require all students to have a grade C or better at GCSE maths	0	0.95
4	Maths is difficult	-0.3	-0.45
5	All teachers need to be good at maths	0.3	0.45
6	I'm **NOT** interested in maths	-0.2	0.65
7	Maths helps you think clearly	0	0.55
8	Maths is too difficult for many people	-0.2	0.05
9	Without good teaching of maths at an early age it is very difficult to become good at it	0.6	0.7
10	Maths is **NOT** interesting	-0.2	0.45
11	Solving problems can be fun	-0.2	0.55
12	Maths is something I **ONLY** do because I have to	-1.0	0.35

Table 5.4: Scores for attitude test

Scores from attitude test

Applying a Student t test to the scores in Table 5.4 gives a probability of less than 1% (0.006093), suggesting that these results are significantly different. One explanation for this is that students re-sitting their GCSE had on average a more positive attitude towards their studies with a realisation that it was an important subject in terms of their future progression either into a job or university. Also the sample of students identified in Table 5.4 as '*All Students*' included a proportion of students who were not studying mathematics at any level and who had achieved very low grades in their GCSE mathematics examinations prior to coming to Exeter College.

For the database of students (see Appendix 8), the cumulative score was recorded for each student. The potential range of scores was from –24, representing an extreme negative attitude, to 24, representing an extreme positive attitude with a score of zero representing a neutral attitude to mathematics. The mean score was 3.3 with a standard deviation of 5.4 with a sample size of 74.

Table 5.5 compares the results from the attitude test for the two groups of students; those that received learning support and those that did not.

	Students receiving learning support	**Students not receiving learning support**
Mean score	1.59	3.86
Standard deviation	5.41	5.25

Table 5.5: Attitude test analysis

In considering the results in Table 5.5 it should be borne in mind that the test was carried out at the start of the GCSE re-sit course; those students seeking support tended to be the least confident students which may be the explanation for the lower attitude score. Although it might have produced a useful comparison to repeat the test at the end of the course this was considered to be impractical, mainly because of difficulties in accessing the students during the period between them sitting their mock examinations and leaving the college. The students sat their mock examinations just before the Easter holiday and were not required to attend the workshops or lessons thereafter.

Last school attended

The school a student had attended prior to coming to Exeter College was considered to be a factor likely to critically affect their performance whilst at the college. Table 5.6 shows the average percentage of students obtaining five or more GCSE's at grade C or above in the years 1999-2001.

School	Percentage of students gaining 5 or more GCSEs at grade C or better
Clyst Vale	48
Cullompton	52
Dawlish	43
Exmouth	43
Priory	27
Queen Elizabeth Crediton	54
St James	30
St Lukes	36
St Peters	62
West Exe Technology College	38

Table 5.6: Feeder schools grading (source: BBC news, 2003)

A score was assigned to each of the schools. This score was the mean of the percentages of students achieving grade C or above in five subjects over the period of the research. The source of this data was the BBC (2003).

5.2 Correlation

The Pearson Product Moment Correlation Coefficient was calculated between each of the parametric variables, and the students' results in the mock examination. Table 5.7 shows the results of this analysis for all students included in the database.

Factor	Pearson		R^2 Coefficient of determination			
	r	r^2	Exponential	Logarithm	Power	Polynomial
Potential	0.3612	0.1305	0.1331	0.1287	0.136	0.1317
Numeracy	0.6704	0.4494	0.4942	0.4215	0.4806	0.4639
Workshop hours	-0.1376	0.0189	0.0368			0.0203
Attitude test	0.2850	0.0812	0.0648	0.0212	0.0395	0.2049

Table 5.7: Correlation results

Comparing the results for Pearson r^2 with the values obtained for the coefficients of determination $\mathbf{R}^2$ shows there is no reason to believe that a non-linear model would be more appropriate for the data. None of the values for Pearson r are high enough to allow predictions of the outcome for individual students to be made. Cohen and Manion (1994) consider a value of r of the order of 0.85 to be required before predictions can be made with an acceptable degree of accuracy. A discussion of any possible relationship between the independent variables is included in section 5.3.

An equation for the line of simple regression for each of the parametric variates against mock examination results together with standard error of estimate was found for each variate. Table 5.8 below gives the coefficients for the variates and standard errors. If the coefficient of the variate were greater than twice the standard error, the result would be considered significant (Krzanowski, 1998). This analysis shows that none of the variates being considered could, by themselves, be considered significant.

Factor	**Standard error of estimate** $s_{estx} = s_x\sqrt{1-r^2}$ (a)	**Coefficient of the Variate** (b)	$\frac{b}{a} > 2$
Potential	1.62	3.140	No
Numeracy	2.37	3.177	No
Workshop hours	14.11	-0.137	No
Attitude test	5.44	0.6995	No

Table 5.8: Standard error of estimate

The following charts show the scatter diagrams with the regression line and residual plots for each variate. When considering the residual plots, where there is no discernable pattern in the distribution of the points this can be taken as an indication that an appropriate model is being used (Clarke and Cooke, 1998).

Figures for Potential Test

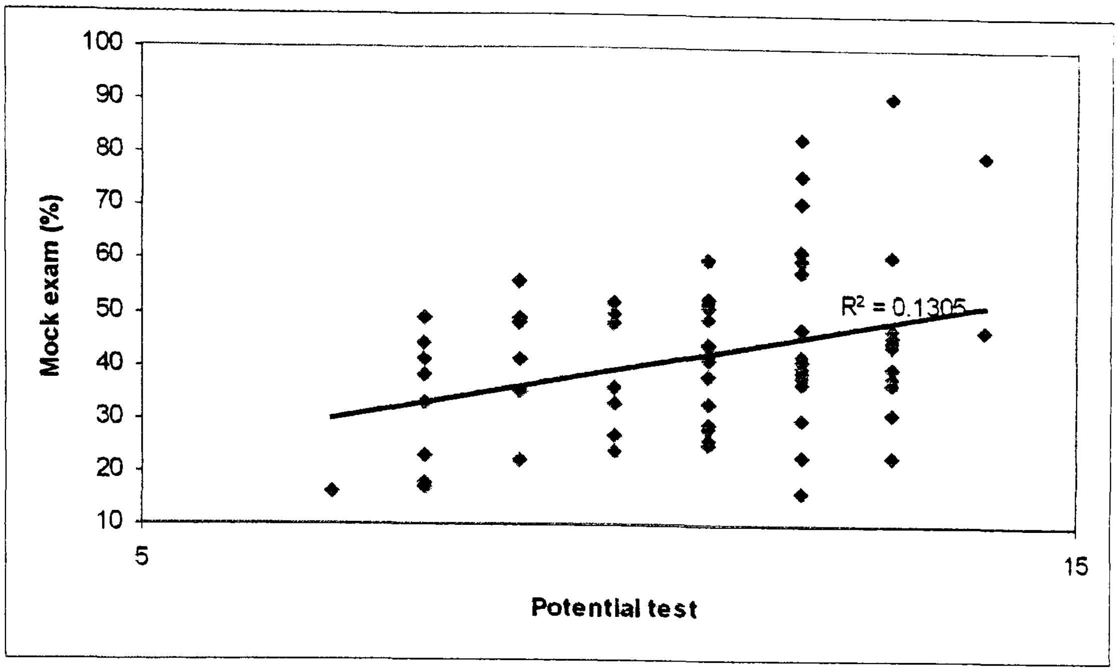


Figure 5.2a: Scatter diagram of potential scores and mock examination results

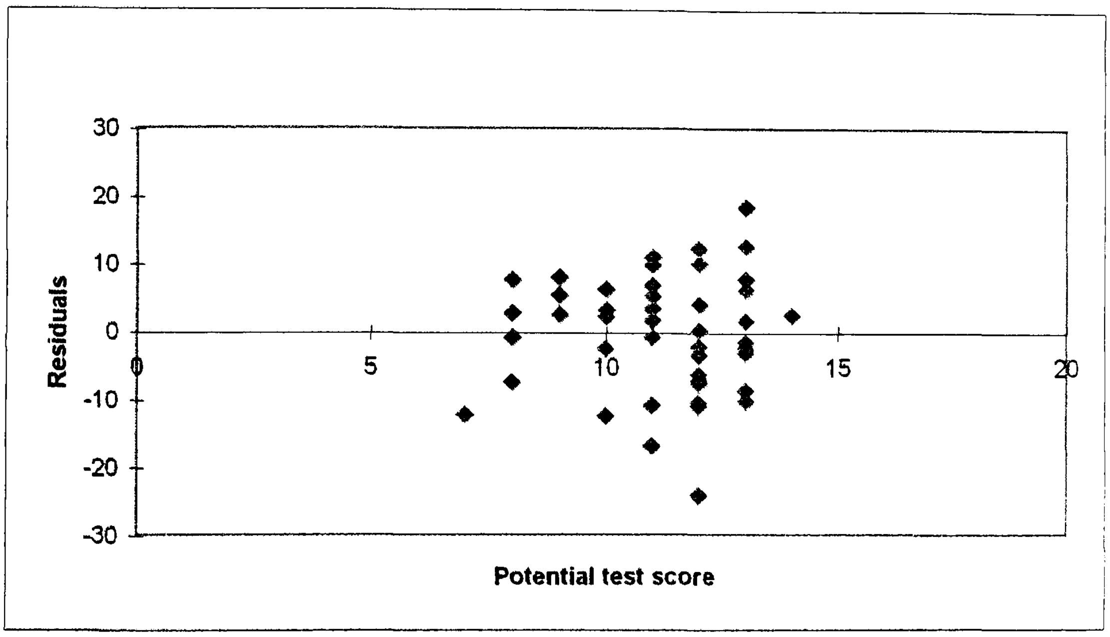


Figure 5.2b: Plot of residuals against potential test scores

Figure 5.2a shows no discernable pattern in the residuals leading to the conclusion that a linear model is appropriate.

Figures for Numeracy Test

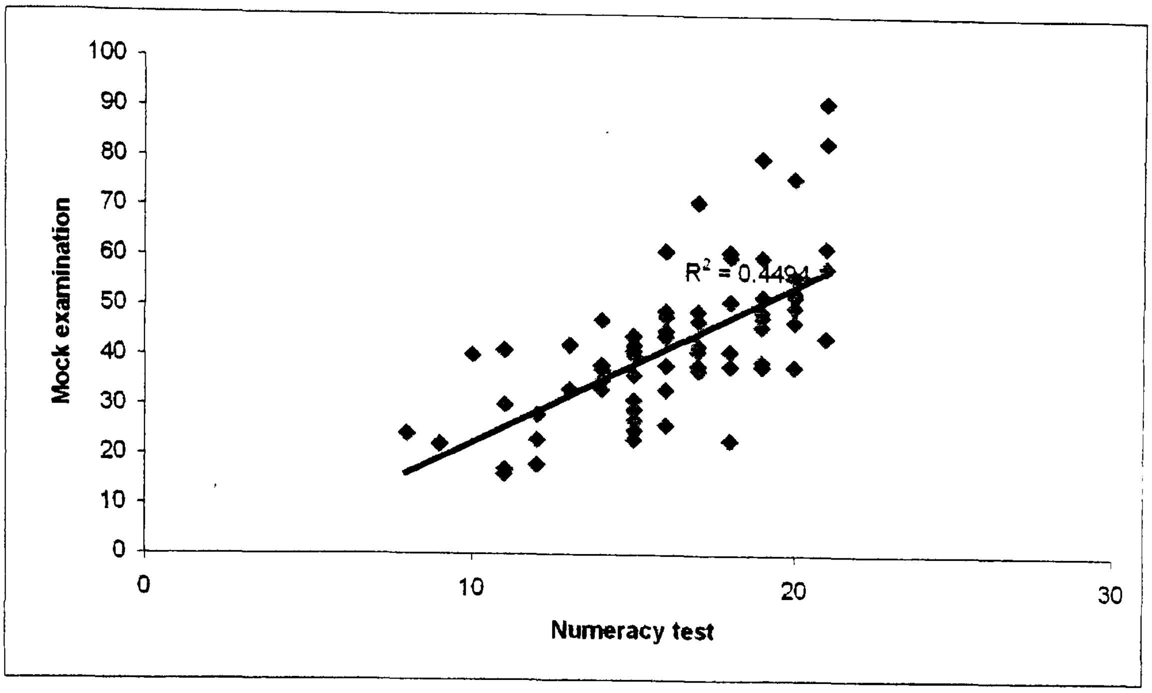


Figure 5.3a: Scatter diagram of numeracy test scores and mock examination results.

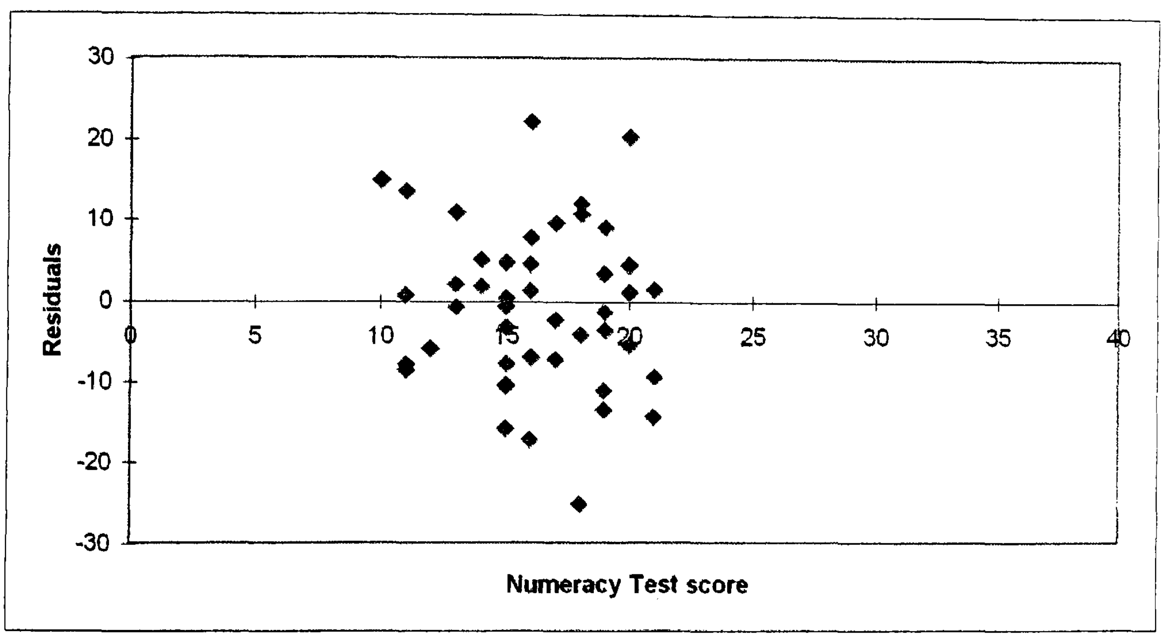


Figure 5.3b: Plot of residuals against numeracy test scores.

Figure 5.3b: shows no discernable pattern in the residuals leading to the conclusion that a linear model is appropriate.

Figures for Workshop Hours

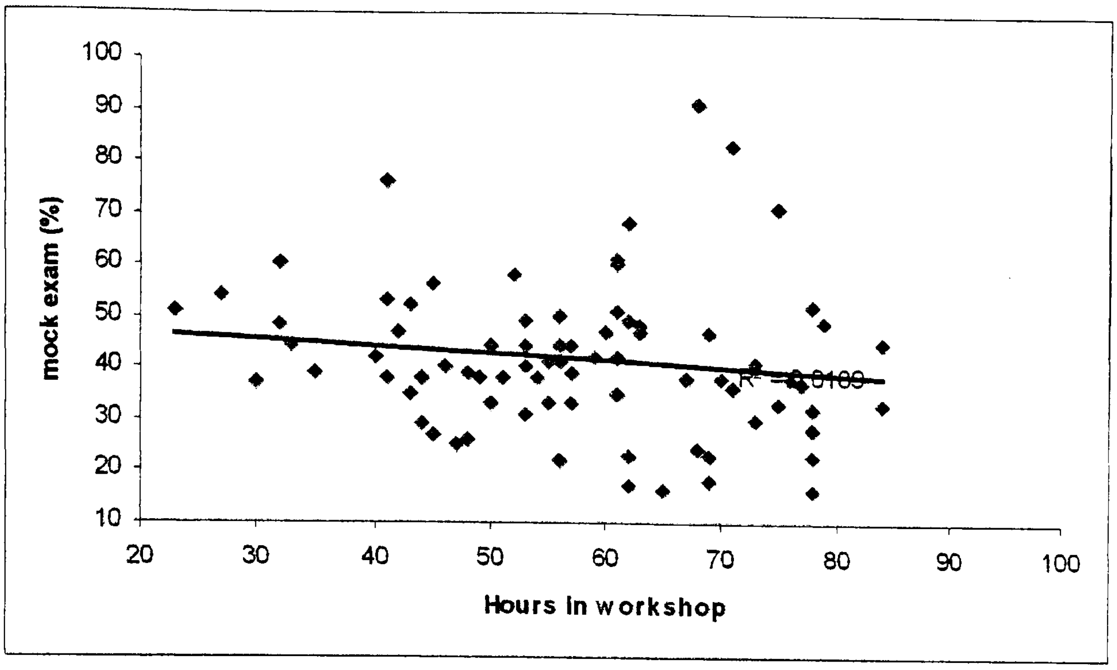


Figure 5.4a: Scatter diagram of hours spent in mathematics workshop and mock examination results.

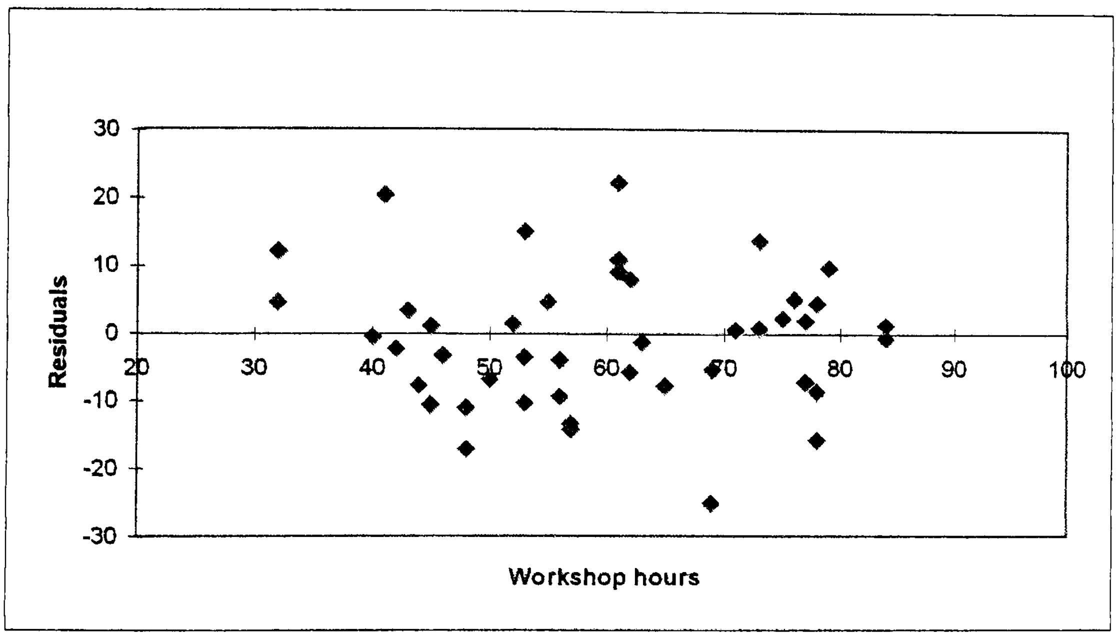


Figure 5.4b: Plot of residuals against workshop hours

Figure 5.4b: shows no discernable pattern in the residuals leading to the conclusion that a linear model is appropriate.

Figures for Attitude Test

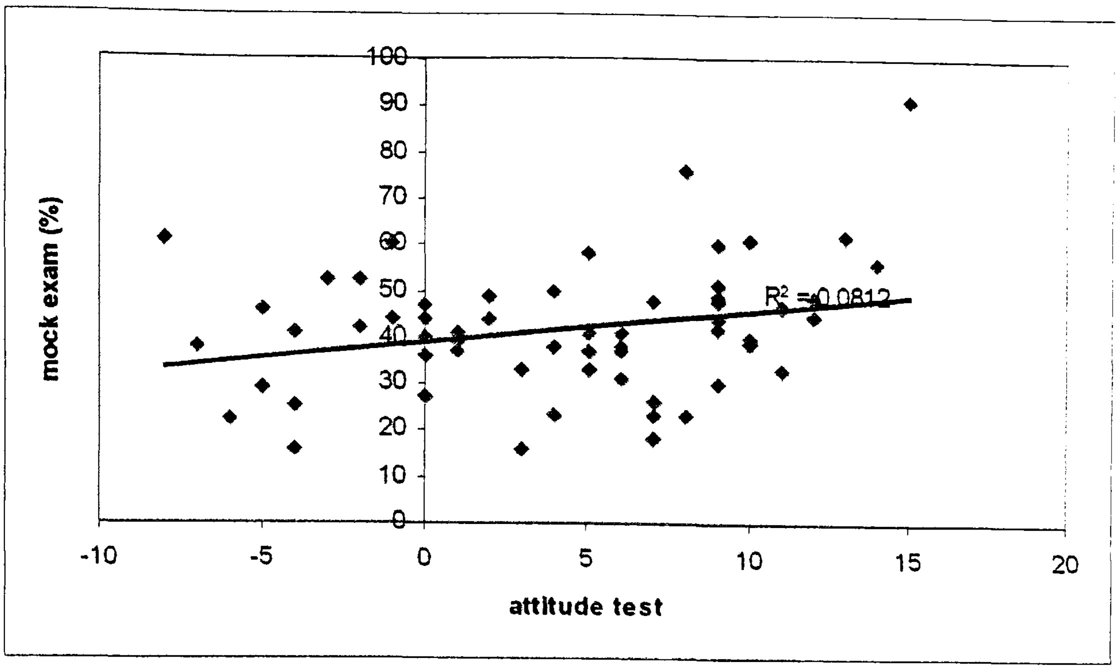


Figure 5.5a: Scatter diagram of attitude test scores and mock examination results

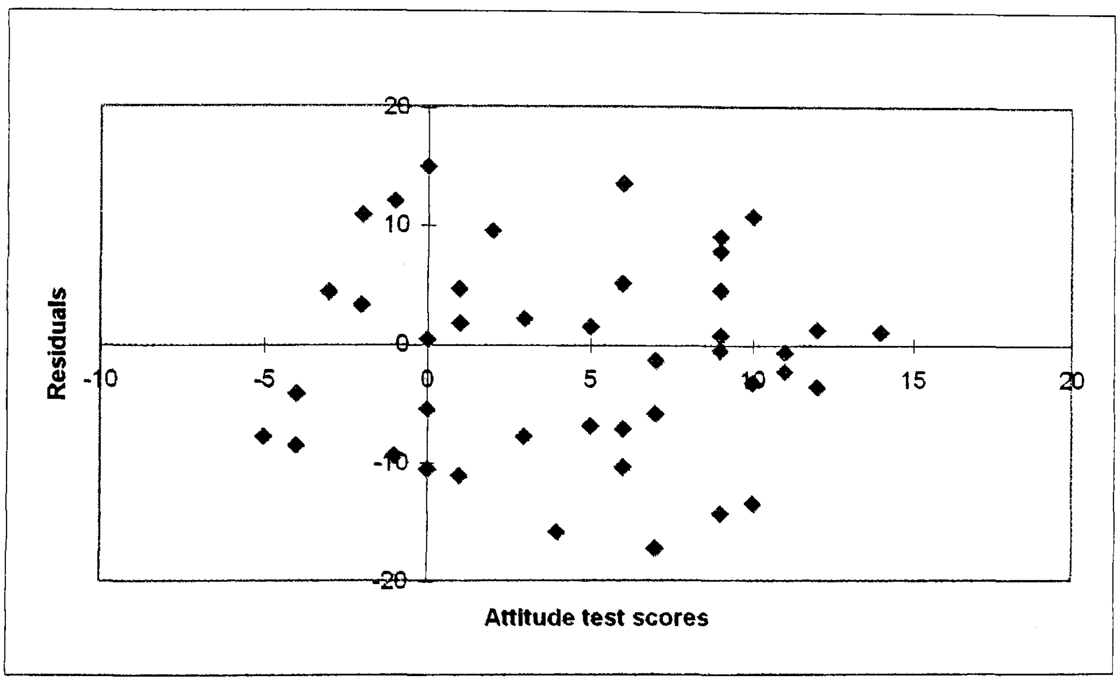


Figure 5.5b: Plot of residuals against attitude test

Figure 5.5b: shows no discernable pattern in the residuals, leading to the conclusion that a linear model is appropriate.

The analysis performed in terms of single variates failed to produce a result that would allow predictions of learning outcomes to be made. This result was not unexpected and in order to achieve a higher correlation figure multiple regression was applied to the data.

5.3 Multiple regression analysis

Section 3.3.2 includes a general discussion of the advantages of using multiple linear regression. In the case of this research it was particularly suitable as a number of the variates were numerical data, in particular the amount of learning support received by students, which varied considerably.

Table 5.9 gives a summary of the results of the regression analysis for all students for whom there were complete records.

Multiple Regression Statistics	
Multiple R	0.71268
R Square	0.507913
Adjusted R Square	0.455722
Standard Error	11.22702
Observations	74

Table 5.9: Regression results for all students

The value of R lies at the lower boundary of values that would allow predictions to be made (Cohen & Manion 1994).

Analysis of variance of regression

	df	Sum of Squares	Mean Square	*F*	Significance *F*
Regression	7	8586.594	1226.656	9.731808	2.91E-08
Residual	66	8319.041	126.0461		
Total	73	16905.64			

Table 5.10: Analysis of variance using the F test

The F-test provides a test of whether the overall regression is significant. The critical value for F for 7 and 66 degrees of freedom, at 5% significance is 2.16. Table 5.10 gives the results for the analysis of variance. The figure of 9.73 greatly exceeds the critical value and hence it can be concluded that the overall regression is statistically significant i.e. the variates are statistically independent.

The regression model

Table 5.11 gives the regression coefficients and the standard errors of the means of the variates for the model derived from the multiple regression analysis.

	Coefficients	Standard Error
Potential test	0.996073	0.840051
Numeracy test	2.837398	0.468885
Level last sat at	26.91969	14.55758
Last school	-0.12762	0.177276
Workshop hours	0.07994	0.082906
Attitude test	0.154085	0.253546
Learning Support	-0.03128	0.201074

Table 5.11: Regression coefficients

When comparing the coefficients against the standard error, the numeracy test emerges as the one significant factor.

Residual plots for the potential, numeracy and attitude test together with those for the workshop hours and learning support are shown in Figures 5.6 to 5.10. These were visually inspected for any linear trend, which if present would suggest that the square of the variable might give a better fit for the data. In fact, none of the residual plots in Figures 5.6 to 5.10 show any discernable trend.

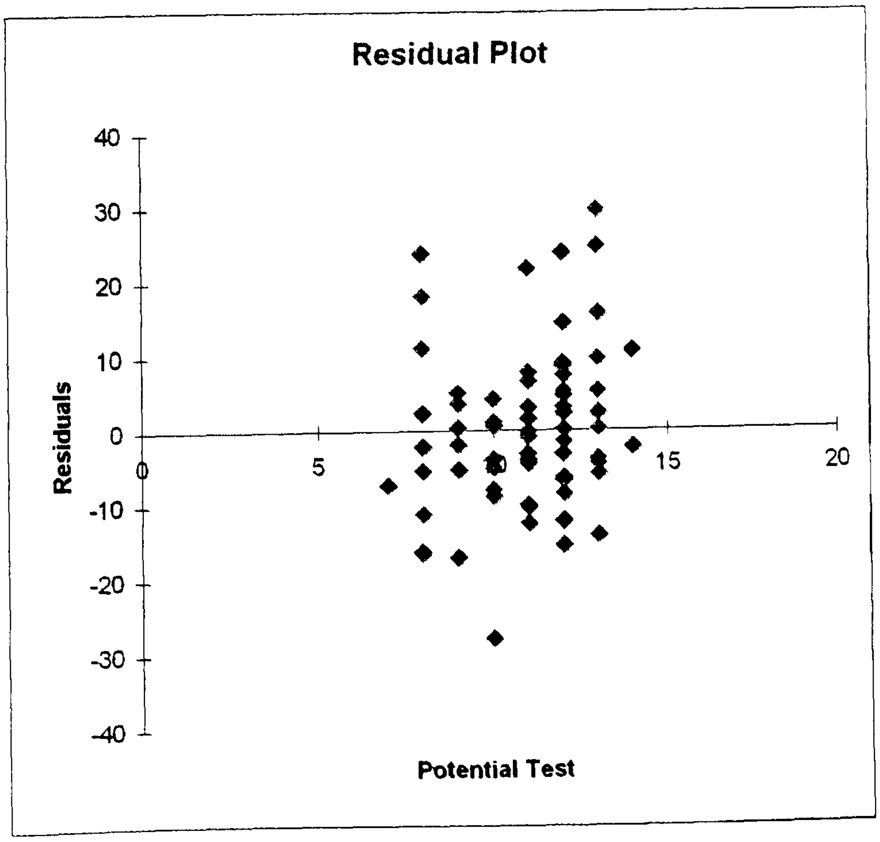


Figure 5.6: Residual plot for potential test

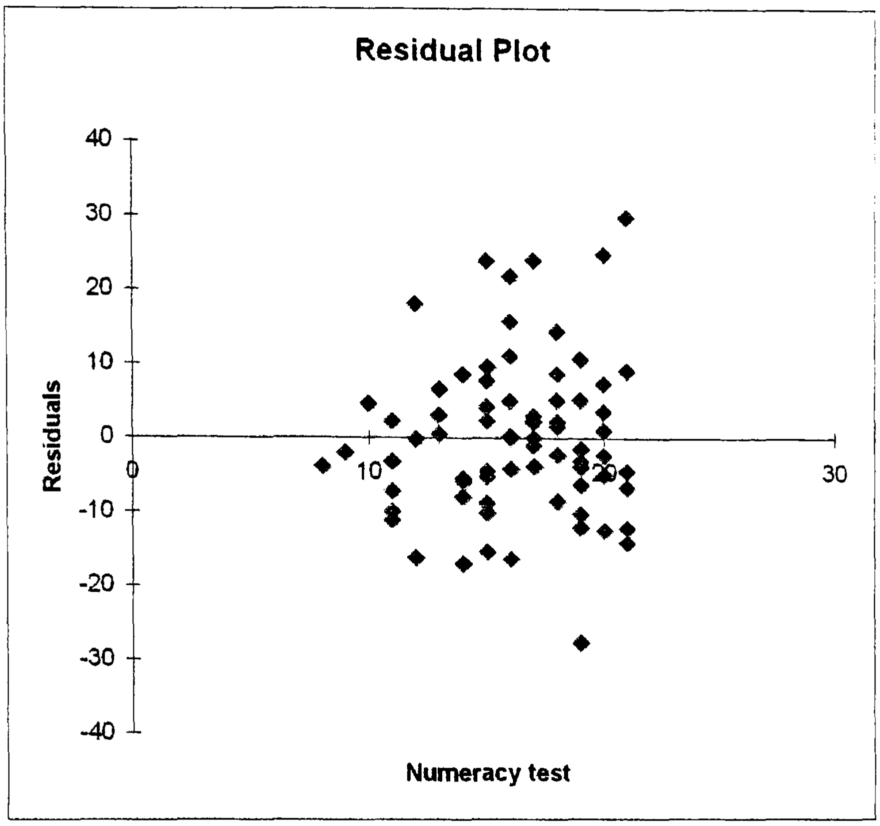


Figure 5.7: Residual plot for numeracy test

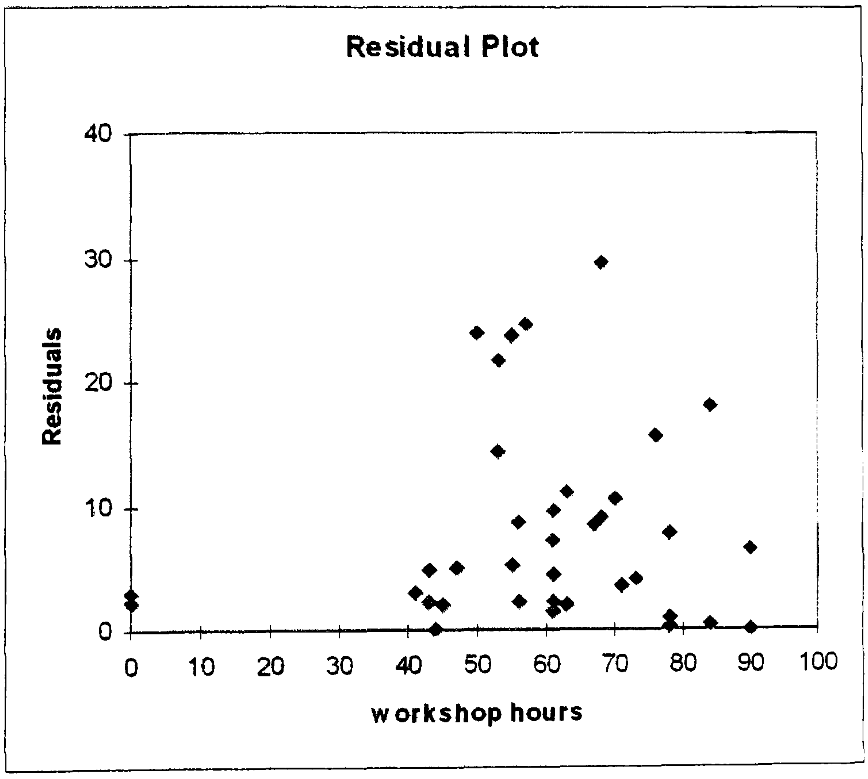


Figure 5.8: Residual plot for workshop hours

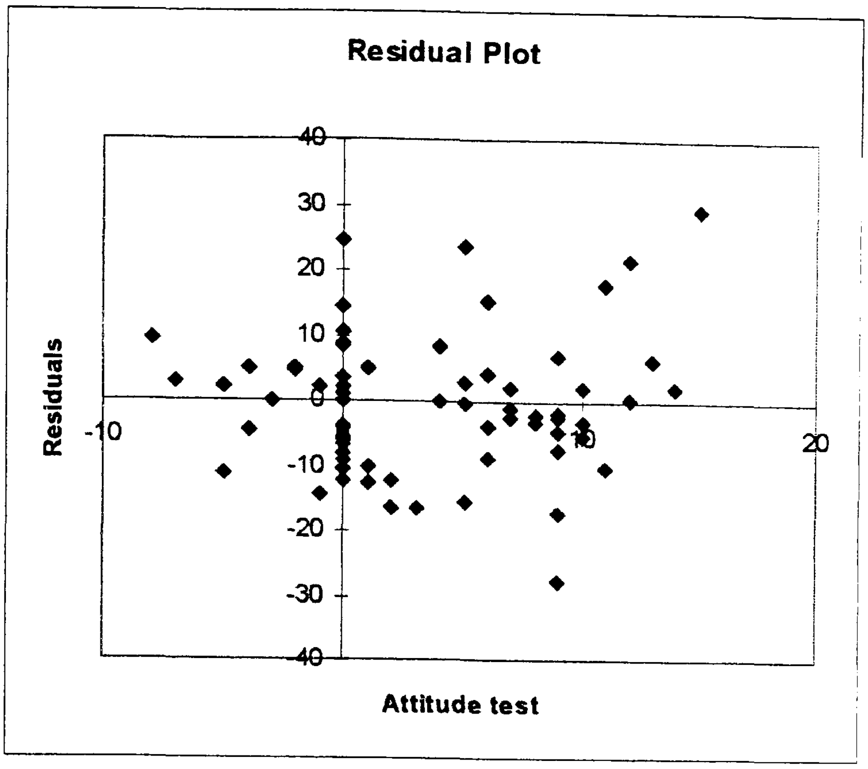


Figure 5.9: Residual plot for attitude test

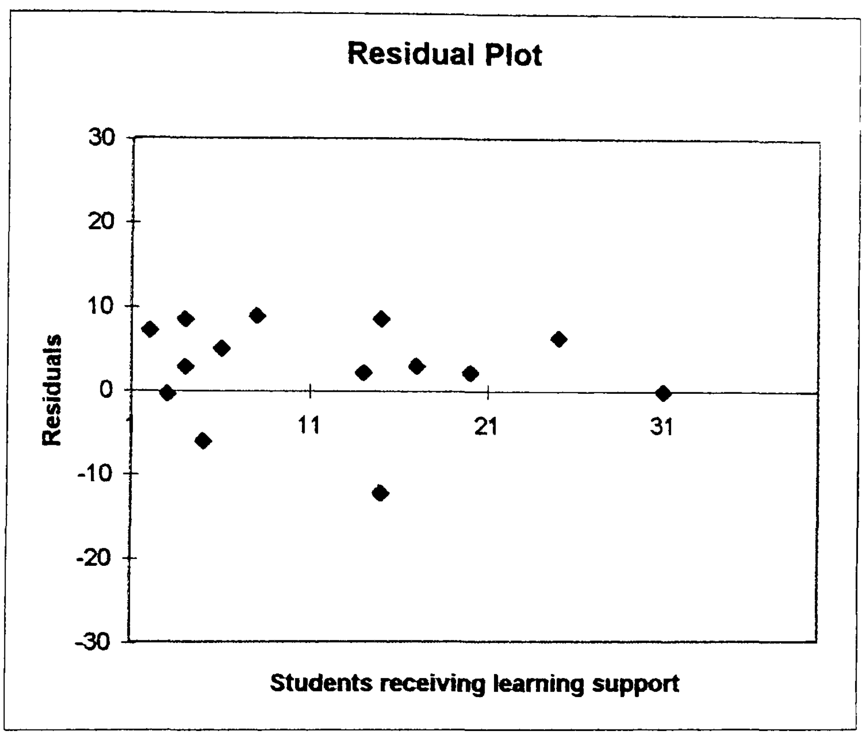


Figure 5.10: Residual plot for learning support

As a further check of the independence of the variates the correlation coefficients between variates were calculated. These correlation coefficients are recorded in Table 5.12. For a sample size of seventy-seven at 5% significance level, a correlation coefficient of less than 0.2216 would not be considered significant. The correlation between the potential test and the numeracy test is significant, suggesting that these two variates were not independent. However repeating the multiple regression analysis without including the results for the potential test produced a lower value for multiple R of 0.705.

	Potential test	*Numeracy Test*	*Level last sat*	*School last attended*	*Workshop hours*	*Attitude*
Potential test	1					
Numeracy Test	0.334268	1				
Level last sat	-0.16191	0.164889	1			
School last attended	-0.1848	-0.01448	0.127407	1		
Workshop hours	-0.00285	-0.27891	-0.22164	-0.13173	1	
Attitude	0.032526	0.173713	0.044289	-0.03156	-0.01471	1

Table 5.12: Correlation coefficients between variates

Three main results emerge from the multi-linear regression analysis. The first of these is that the multi-linear regression has produced a correlation coefficient only slightly higher than that for the numeracy test alone. The second is that the numeracy test is the only significant variate to emerge from the analysis. Thirdly the results indicted that the potential test and numeracy test are not independent variables.

Regression analysis for students receiving learning support

Multiple regression analysis was also carried out solely on the records of students receiving learning support; this included students who received their support with DVC and those receiving face-to-face tutorials. Table 5.13 summarises the results of this analysis. The correlation coefficient for this group of students is significantly higher than for the whole group and at a level where it should be possible to make predictions using the model.

Regression Statistics	
Multiple R	0.909888
R Square	0.827896
Adjusted R Square	0.694037
Standard Error	6.901702
Observations	17

Table 5.13: Regression results for learning support students

The further analysis of these results follows the same format as above.

Analysis of variance of regression

The critical value for the F test based on this sample of students is 3.29. It can be seen from Table 5.14 that the computed value exceeds the critical value and again it can be concluded that there is a significant difference between the variates.

	df	Sum of Squares	Mean Square	F	Significance F
Regression	7	2062.24	294.6057	6.184843	0.007228
Residual	9	428.7015	47.6335		
Total	16	2490.941			

Table 5.14: Analysis of variance

Table 5.15 below shows that the numeracy test together with the last school attended are significant variates.

	Coefficients	Standard Error
Potential test (P)	-0.79775	1.393714
Numeracy test (N)	2.964251	0.616201
Level last sat at (S1)	-6.43822	20.16735
Last school (S2)	-0.57725	0.274262
Workshop hours (W)	0.037901	0.104057
Attitude test (A)	0.253441	0.355397
Learning support (LS)	0.032151	0.195123

Table 5.15: Regression coefficients

As before the residual plots for five of the variates follow in Figures 5.11 to 5.15. None of these residual plots show any discernable trend.

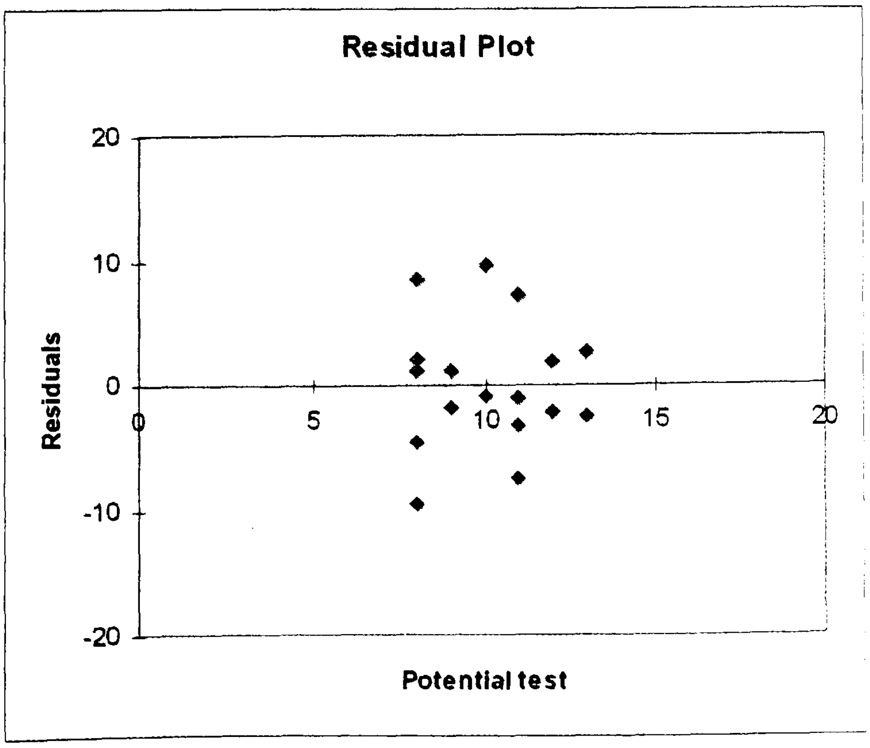


Figure 5.11: Residual plot for potential test

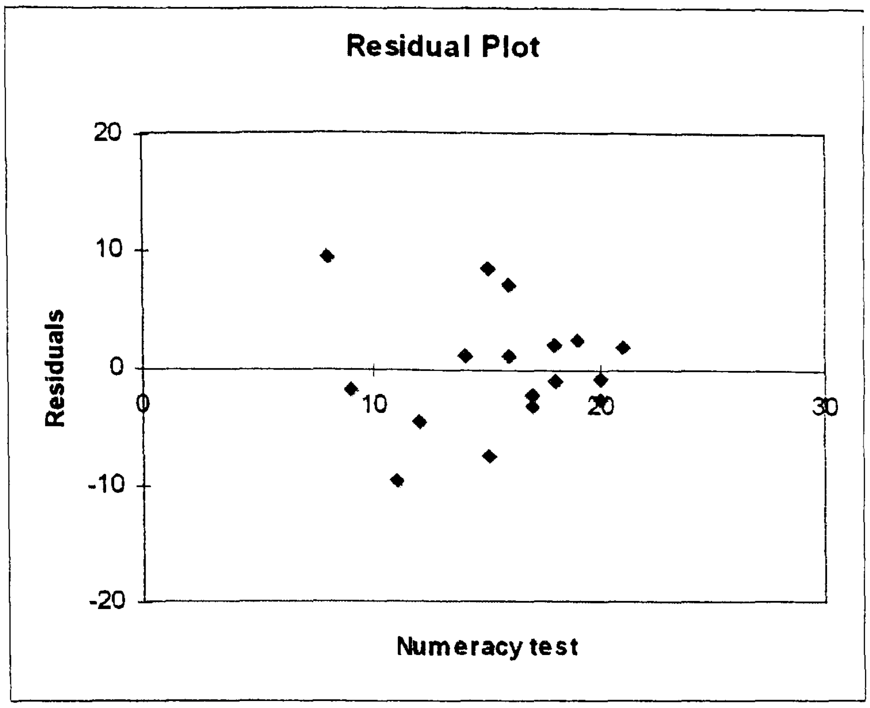


Figure 5.12: Residual plot for numeracy test

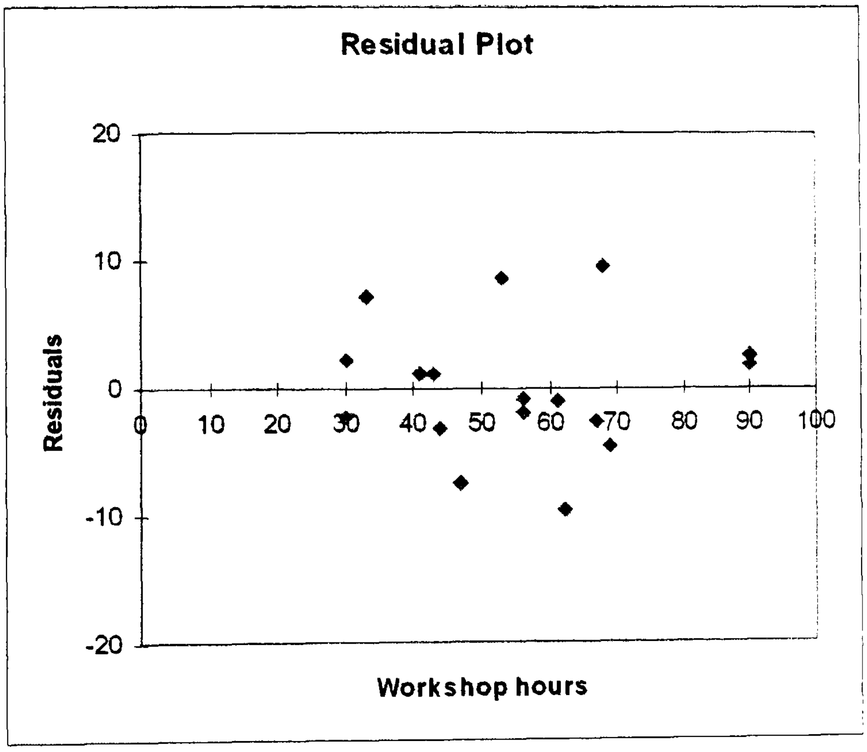


Figure 5.13: Residual plot for workshop hours

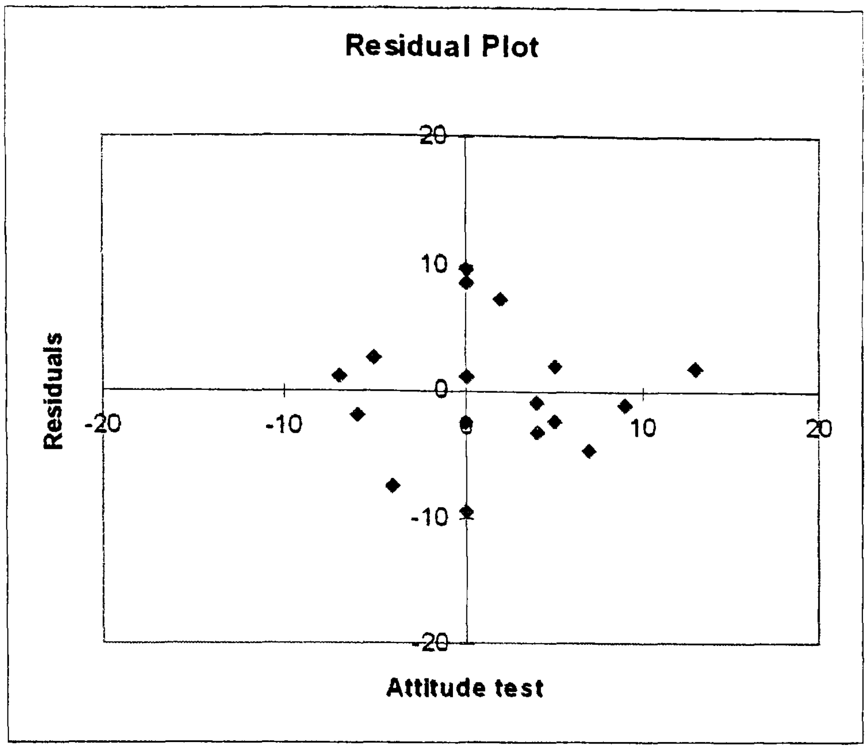


Figure 5.14: Residual plot for attitude test

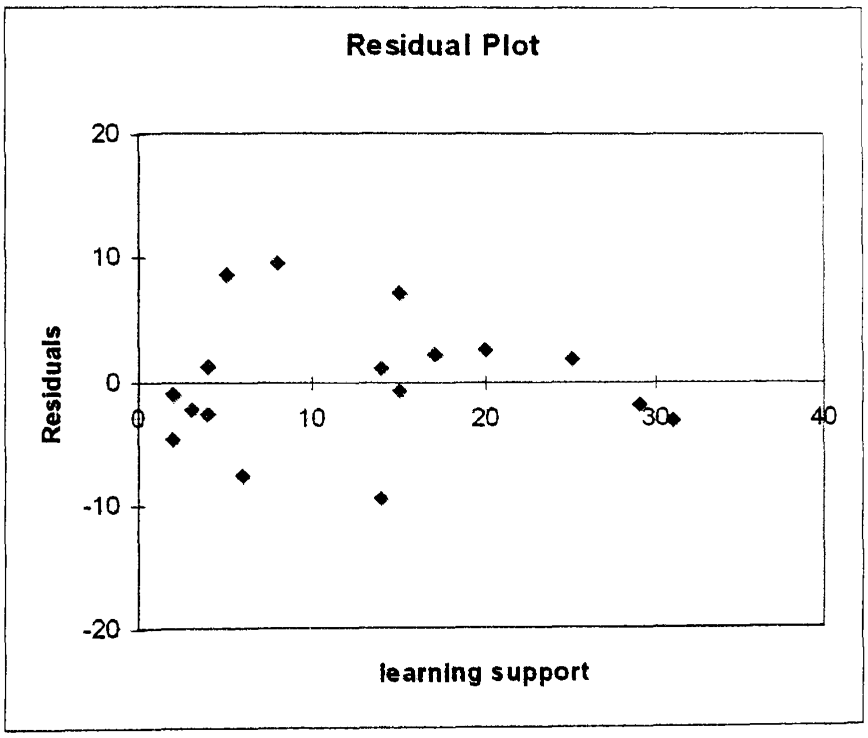


Figure 5.15: Residual plot for learning support

The model

The model derived from this analysis can be expressed as:

Predicted Mark = (-0.79775)P + 2.964251N + (-6.43822)S1 + (-0.57725)S2 + 0.37901W +0.253441A + 0.032151L + 30.84504

The variates and their coefficients are defined in Table 5.15. The constant term is produced by the statistical analysis.

Since the value for multiple **R** obtained for the analysis of learning support students is high, this suggests that this model might produce acceptable predictions of learning outcomes for all students. Applying this model to all seventy-four students included in the analysis produced the following results.

Predicted mark	Actual mark	Predicted mark	Actual mark
41	38	38	39
24	22	35	38
60	62	57	38
44	46	46	38
39	41	45	37
51	50	37	37
37	44	35	36
34	35	34	33
27	17	39	33
15	24	36	33
33	25	32	33
35	44	42	31
37	38	36	30
41	38	31	29
39	37	26	28
52	51	34	27
23	18	38	26
54	91	44	23
51	83	24	23
44	80	29	23
49	76	26	16
40	71	29	16
44	61	43	49
33	61	40	48
61	60	55	48
54	60	42	47
52	58	55	47
53	56	38	47
48	53	40	45
45	52	52	44
43	52	60	44
53	49	33	42
41	49	27	42
39	41	39	42
43	41	24	41
33	40	40	41
18	40	49	39

Table 5.16: Predicted results and actual results for all students

A two-tailed Student *t* test for matched pairs was carried out on the results in Table 5.16 in order to compare the predicted result with the actual result. This test returned a probability of **0.085**. At a 5% significance level we can conclude that there is no significant difference between the predicted and actual results, that is to say that they are drawn from the same population. The

Pearson Product Moment Correlation Coefficient between the predicted and actual results yielded a figure of 0.628. The lack of any significant difference together with the low correlation coefficient suggest that considerable caution would need to be used when applying this model and in practice it is unlikely to produce useful results.

However if a Student *t* test is applied to the predictions for only those students who received learning support the test gives a probability of 0.9997. This suggests that for those students receiving support the model represents a good predictor of the outcome.

Further correlation coefficient analysis

In view of the high correlation coefficient obtained in the multiple regression analysis for just those students receiving learning support, compared to that for all students, further analysis of the Pearson correlation coefficients for the two groups of students was carried out.

The results of this analysis are included in Table 5.17.

Variate	Pearson correlation coefficient for students receiving learning support	Pearson correlation coefficient for students NOT receiving learning support
Potential test	0.448	0.302
Numeracy test	0.838	0.633
Workshop hours	0.147	-0.056
Attitude test	0.456	0.110
Last school attended	-0.205	-0.036

Table 5.17 Pearson correlation coefficients for the two groups of students

As with the previous analysis the numeracy test produces the highest correlation coefficient. However, unlike the previous analysis, the value obtained for the correlation coefficient for the numeracy test for students receiving learning support is of a magnitude that suggests that it could be used as a reasonable predictor of outcome with regards the mark obtained by a student in their mock examination.

Also of note, in Table 5.17 is the relatively high value of the correlation coefficient obtained for the attitude test for those receiving learning support.

In view of the small sample size,(seventeen in total) of students receiving learning support these results again need to be treated with caution. They do however suggest an interesting avenue for further research.

5.4 Conclusions

The fact that no distinction was made between the forms of learning support together with the high coefficient of determination obtained suggests there is no significant difference between the two forms of tutorial support, as measured against the outcome from examinations.

As far as being able to accurately predict a student's likely result the most significant indicators are the scores from the numeracy test and the school they last attended.

Using the data collected for students receiving learning support, the model developed provides predictions that are not significantly different from those actually obtained.

With regard to student retention rates, the results suggest that DVC may increase the rate amongst students receiving learning support. The increase in retention rate amongst all students receiving learning support was in line with other research (Basic Skills Agency, 1997).

Chapter 6 Results from Discourse Analysis

6.0 Introduction

Discourse analysis was applied to transcripts and recordings of both the face-to-face and DVC tutorials. The objective of this analysis was to answer the following two research questions.

i. Is DVC a medium that allows the characteristics of Laurillard's Conversational Framework, (conditions she considered essential for teaching and learning, to take place) to be met?

ii. Are there any identifiable differences in the structure of discourse between DVC and face-to-face tutorials? This is to be examined by applying Stubbs' idea of Exchange Unit classification.

Inevitably the format, content, and pace of a tutorial will vary considerably depending on the tutor, the student and the topic being studied. These differences made the comparisons of different tutorials extremely problematic. To mitigate these effects comparisons were made between tutorials (both face- to- face and DVC) that involved the same student and tutor pair. Of the two tutors who took part in the research tutor **A**, the author, was experienced in the use of DVC, and tutor **B** had no experience of DVC. Whilst agreeing to have his tutorials recorded tutor **B** was not aware of the form of analysis that would be applied or the purpose of it. This was to mitigate the possibility of the outcomes being prejudiced by his actions, however unintentional.

This chapter looks first at an analysis applied to audio only transcripts of DVC tutorials with regard to the Conversational Framework. Secondly it looks at two distinctly different tutorial types in order to consider the structure of the discourse. The two types of tutorial have been termed:

i. Concept-centred, which means the tutorial was mainly conducted within the top part of Laurillard's Conversational Framework. This implies that the tutor was endeavouring to help the student towards an understanding of a topic; consequently the majority of the dialogue is by the tutor.

ii. Task-centred, which means the tutorial was mainly conducted within the bottom part of the Conversational Framework. Here the student is problem solving and is therefore likely to be working within the zone of proximal development (see Chapter 2.1.2) with the tutor assisting the student as required.

In the analysis of both types of tutorial no attempt was made to record such things as eye contact, facial expressions or other body language. Whilst with face-to-face tutorials these aspects were readily available to both participants, in the case of the DVC tutorials these were only available in limited form if a participant chose to display the video image of the other. Further discussion of how much the video image was used is included later in this section.

Data collection.

Several different recording techniques were used during the course of the study; in each case the whiteboard images and written text were retained. The types of recording are identified as follows.

A - Audio recording with a Dictaphone i.e. the dialogue of both student and tutor were recorded independently from the computer.

B - Audio and video recording using Lotus Screencam (not used in the discourse analysis due to the poor sound quality and the large size of the files).

C - Audio and video recording using Quickcam.

(Methods B and C recorded the computer screen image and the conversation simultaneously making it easy to match the written work with the corresponding dialogue).

Tutorial ref	Type	Tutor	Student	Recording method	Student working level	Spoken Words per min
1	DVC	A	C	A	GCSE	100
2	Face-to-face	A	C	A	GCSE	86
3	DVC	B	D	A	'A' level	97
4	DVC	B	E	A	'A' level	115
5	DVC	B	F	A	'A' level	99
6	DVC	B	G	C	'A' level	104
7	DVC	B	H	C	'A' level	50
8	DVC	B	I	C	'A' level	Not analysed
9	Face-to-face	B	G	C	'A' level	131
10	Face-to-face	B	H	C	'A' level	80

Table 6.1: Summary of tutorials discussed in chapter 6

It can be seen from Table 6.1 that there are pairs of tutorials that involve the same tutor and student, where each tutor delivers tutorials using both DVC and face-to-face, with the same student. Tutorials 1 and 2 involved the author (tutor **A**) and a partially sighted GCSE student A; 6 and 9 were conducted with tutor **B** and student **G**; 7 and 10 were tutor **B** and student **H**. With the transcripts of tutorials 1 and 2 the word rate is higher for DVC than for face-to-face, the opposite being the case in tutorials 6,9,7 and 10. However it should be noted that for tutorials 6,7,9 and 10 the tutor and students were both relatively inexperienced in the use of DVC and this is felt to be a likely explanation for the decrease in the word rate. The high word counts for the DVC tutorials suggest that this technology does not inhibit speech. The significant difference in word rate between tutorials 6,9,7 and 10 is considered later.

6.1 Discourse analysis applied to audio only transcripts of DVC tutorials

The first objective of this part of the research was to apply discourse analysis to investigate whether the characteristics of Laurillard's Conversational Framework could be met through the medium of DVC. In practice, transcripts of the audiotapes were found to be difficult to produce, because the typist did not recognize the technical language relating to mathematics used in the tutorials. Whilst it was possible to use an analysis of these transcripts to provide evidence that the characteristics required for learning and teaching to take place were being met (see chapter 2 section 2.2 for details) they contributed little to a detailed analysis of dialogue structure. The big limitation of the transcripts produced from audiotape recordings was that the non-verbal dialogue e.g. an activity using the whiteboard, was not recorded simultaneously. Although the final version of the whiteboard or paper was available during the analysis, it was found to be difficult to determine which piece of the written work corresponded to which piece of dialogue.

The following sections of dialogue are taken from the transcript of tutorial 3 (see Figure 9.1 Appendix 9 for the full transcript). The dialogue was recorded on audiotape and a record of the whiteboard was saved into the computer. The tutorial involved a first year 'A' level student (**D**) and tutor **B** neither of whom had used the equipment before although the tutor had familiarised himself with the whiteboard before the tutorial began.

The tutorial focussed on differentiation and how key results can be derived from first principles. The following extracts demonstrate that each of the eight observable characteristics of Laurillard's Conversational Framework can be met during a DVC tutorial.

1. **Tutor can describe conception**

> *What is going to happen is we will look at what it is for a general h, when we know it is going to be small and then eventually let* ***Q*** *get closer and closer to* ***P****. In other words let h get smaller. That's the limiting process; you've got to picture h getting tinier and tinier. As* ***Q*** *gets closer to* ***P****, the line joining* ***P*** *to* ***Q*** *will eventually become part of the curve. It will be so close that the line is almost indistinguishable from the arc of* ***PQ*** *on the curve.*

2. **Student can describe conception**

"So the whole point of differentiation as I understand it is to find the gradient at a point on a curve?"

3. **Tutor can re-describe in light of student's understanding of conception or action**

"Usually what you do is that. Say ***P*** *is the point you were just talking about (3,9), then* ***Q*** *will be a little bit further away from it say* ***X****= 3.1"*

4. **Student can re-describe in light of tutor's re-description or student's action**

"Yes that's what I was going to do. The change in y is $(3\text{-}h)^2\text{-}9$*."*

5. **Tutor can adapt task goal in light of student's description or action**

Non-observable

6. **Tutor can set task goal**

"What you need to do is expand that, this thing on top in the numerator."

7. **Student can act to achieve task goal**

"Right you've got $(3+h)^2$ *so you are going to get* $9 + 3h + 3h + h^2$*, so then you get, overall, because the minus 9 and plus 9 will cancel out; you get* $h^2 + 6h$*, I think"*

8. **Tutor can set up world to give intrinsic feedback on actions**

" Yes, so the numerator is $\boldsymbol{h}^2 + 6\boldsymbol{h}$*, that's fine. The 9s have gone; so don't forget to divide by* ***h*** *as well."*

9. **Student can modify action in light of feedback on action**

" So that's all over h, so then.... that's going to cancel out with that"

10. **Student can adapt actions in light of tutor's description or student's re-description**

Non-observable

11. **Student can reflect on interaction to modify re-description**

Non-observable

12. **Tutor can reflect on student's action to modify re-description**

Non-observable

Although this extract shows that the characteristics of Laurillard's Conversational Framework are being met using DVC the dialogue is difficult to follow and little can be determined about the structure of the discourse and the format of the Exchange Units.

6.1.1 Problems with applying discourse analysis.

The application of traditional discourse analysis (verbal communication only) to transcripts, such as the extract from tutorial 3 (see Figure 6.1 below), proved to be both difficult and of little help since it quickly broke down, frequently showing ill-formed exchange units.

Consider the following section of transcript taken from tutorial 3 where all communication, other than verbal, has been removed. It can be seen that of the seventeen brief exchanges, five were ill informed (these are indicated by the asterisk), that is, they failed to follow an accepted sequence.

S	Yes the equation is (***writes equation down***) okay?	[I
T	I thought it might be something like that. I had a feeling it might be. Yeah Ok right	R]
T	Right okay	[R]*
S	So h is the............what the x distance between P and Q?	[I
T	yes so then P (interrupted)	R/Ir
S	So where is P, has P gone up	Ir*
T	P is at, actually do you ; no you don't have the pure maths	R/Ir/R*
S	No I haven't got it with me	R]
	All I know is y = 9, so I think x= 3.	[R
T	Ok	F]*
S	You want to know the co-ordinates of	[I]*
T	So that is your Q?	[I
S	No that's just for the – I'm not sure what that is for	R]
T	***Usually what you do is that say P is the points you were just talking about (3,9). Then Q will be a little bit further away from it. like 3.1;*** **(3)**	[Inf
S	Right	F]
T	Is that what you were going to do?	[I
S	***Erm yeah its what I was going to do, the delta Y is $(3 + h)^2 - 9$ is what I have got down here*** **(4)**	R
T	That's fine	F]

Figure 6.1: Extract from tutorial 3

Without knowledge of the equation that has been written down the remaining dialogue is essentially meaningless to a third party. While some ill-formed exchanges may be as a result of interruptions, others may well have not occurred had the non-verbal part of the dialogue been recorded. This is discussed again later in this section.

The reason that the transcript in Figure 9.1 (Appendix 9) is both difficult to follow and analyse is that much of the discourse is in fact not being recorded. Whilst the above demonstrates that the characteristics of the Conversational Framework can be met with DVC, it does not demonstrate that they are being met within a well-constructed discourse, nor does it consider the non-verbal communication that formed part of the dialogue. In order for a medium such as DVC to provide both an environment in which learning and teaching will have a successful outcome, and meet the characteristics defined by Laurillard, the discourse must also be well structured. Satisfying the characteristics within a well-structured dialogue is a necessary but not sufficient condition to guarantee a satisfactory learning outcome.

6.2 Analysis using the modified framework

Once it was realised that the non-verbal dialogue formed a significant and integral part of the discourse, subsequent analysis was carried out using the modified Conversational Framework (see Chapter 3, section 3.4). The non-verbal discourse did not include any body language but was limited to written work and actions such as pointing. The method of recording tutorials was altered to allow for the capture of the screen, in particular the whiteboard, at the same time as the conversation. The first method used was to record the tutorial into the computer using 'Lotus ScreenCam 97'but this soon proved to be unsatisfactory as the files created were to large to manage (over 1 GB per hour) and the quality of the audio recording from the remote computer was very poor. The recording method that proved most satisfactory for both DVC and face-to-face tutorials was Logitech Quickcam and simultaneously saving the whiteboard in the case of DVC tutorials or copies of written work if the tutorial was face-to-face. The Logitech Quickcam recordings captured a visual image of either the screen (in the case of DVC) or of the paper (in the case of face-to-face tutorials) together with an audio recording in each case. Transcription of the recordings was found to be easiest if the files were opened using Windows Media Player as this allowed better control. This approach enabled each non-verbal action to be set in the correct context of the verbal dialogue. Images of the tutor and student were not recorded unless the image was brought up on the screen, as was the case with DVC.

Four sections of transcript were analysed (see Appendix 9 for the transcripts). The first two tutorials were concept centred i.e. the student was attempting to grasp ideas and hypotheses applicable to the topic and the other two were task centred where the student was applying their understanding by working through exercises. The characteristic in column two refers to the characteristics of Laurillard's Conversational Framework (see section 2.2.2). It can be seen that although not all the dialogue necessarily satisfies a characteristic, each interaction can be identified in terms of part of an Exchange Unit i.e. initiation [I], response [R] or feedback [F].

6.2.1 Comparison of transcripts from concept centred tutorials (6 and 9)

Transcripts from tutorials 6 and 9 were used for the analysis of concept centred tutorials. They both involved tutor **B** and student **G**, a mature first year 'A' level mathematics student and were of equal duration (seven minutes and forty-five seconds). Table 6.2 provides some statistics for each of the tutorials.

	DVC	**Face-to-face**
Words spoken	804 (Word rate 104 per min)	1016 (Word rate 131 per min)
Written sequences	14	16
Number of exchanges	38	54
Number of exchange units	9	13

Table 6.2: Statistics for concept centred tutorials

The two transcripts were compared and two initial observations were made (see Figures 9.2 and 9.3, Appendix 9 for transcripts). The first observation was that there is a significant difference in the rate of speech. However, if these two figures are compared with those for other tutorials quoted in Table 6.1 of the introduction it can be seen that the rate for this DVC tutorial is consistent with other DVC tutorials whilst that for face-to-face tutorials is considerably higher. Consideration of the face-to-face tutorial suggests this might be due to the topic under consideration. For example 3^{-4} involves eight words when spoken, (three raised to the power of minus four).

The second observation was that the amount of written work produced varied considerably between tutorial types. In the DVC tutorial both participants shared the whiteboard whereas in the face-to-face tutorial the tutor did all of the writing. Table 6.3 gives an approximate split of the written work carried out by both participants during one-to-one tutorials. The written work comprised letters, numbers, mathematical notation, diagrams, corrections and feedback and as no way could be thought of for quantifying this, the percentage split for the written work is based on a visual inspection of the work.

An inspection of other tutorials suggests that the whiteboard allows for more participation by both participants than does the use of paper. Clearly the whiteboard avoids participants needing to either pass paper to the other or reaching over to write which could well inhibit the participants' ability to write. In the DVC tutorial the tutor has used the highlighter to reinforce what is being said (see line 16 & 18, tutorial 6, Figure 9.2, Appendix 9). During the face-to-face tutorials the technique of pointing at working on the paper was used to place emphasis on a particular part of the work.

Tutorial ref.	Type	Tutor	Student	Student working level	Type of tutorial. TC – task centred CC – concept centred	Percentage of written work done by tutor	Percentage of written work done by student
1	DVC	A	C	GCSE	TC	60	40
2	Face-to-face	A	C	GCSE	TC	50	50
3	DVC	B	D	A	CC	50	50
4	DVC	B	E	A	TC	50	50
5	DVC	B	F	A	TC	45	55
6	DVC	B	G	A	CC	40	60
7	DVC	B	H	A	TC	5	95
8	DVC	B	I	A	TC	2	98
9	Face-to-face	B	G	A	CC	100	0
10	Face-to-face	B	H	A	TC	0	100

Table 6.3: Comparison of written work during tutorials

The tutorials, which have been classified as concept centred, show a clear difference between the two types of tutorial. This may be a characteristic of the tutor or the subject content of the tutorial. However, looking at the associated transcripts there is evidence of a positive effort on the tutor's part to encourage the student to write on the whiteboard when using DVC, whilst when working face-to-face the tutor tends to write down almost all of what he has said. The sample size is too small to draw any firm conclusions on this point.

The discourse analysis shows that both types of tutorial contain a well-structured dialogue, since there are no ill-formed exchanges. The analysis also shows that both types of tutorial provide a medium within which the characteristics of the Conversational Framework can be met.

6.2.2 Comparison of task centred tutorials (7 and 10)

The second pair of tutorials to be compared involved tutor **B** and student **H** who was in his first year of an 'A' level mathematics course and who had received support from the same tutor whilst studying GCSE mathematics at the college. In the context of the Conversational Framework these tutorials were conducted within the task centred part of the framework as the student was applying their knowledge to a given task, i.e. working through topic-based assessment sheets. Table 6.4 summarises the statistics for the task centred tutorials.

	DVC (Figure 6.6)	Face-to-face (Figure 6.5)
Duration	5 min 7 seconds	4 min 20 seconds
Words spoken	255 (word rate 50 per min)	348 (word rate 80 per min)
Written sequences	6	6
Number of exchanges	36	43
Number of exchange units	20	20

Table 6.4: Statistics for task centred tutorials

As with the previous two transcripts the rate of words spoken is noticeably higher during the face-to-face tutorial than with DVC (see Figures 9.4 and 9.5 Appendix 9 for transcripts). When asked about this tutor **B** expressed surprise and thought the converse was probably true; he was unable to offer an explanation for this dilemma. This effect may be due to one or more of the following four factors:

i. The tutor had a clearer view of what was being written and hence less inclination to restate what had previously been written, plus having a clear view of the student's work made it

ii. The lack of non-verbal cues (body language) as the result of the video image of the student not being viewed during the main part of the tutorial.

iii. Not wishing to talk over the other participant. However as the sound operates in duplex mode this would not present a problem.

iv. Lack of familiarity with the hardware and software.

Table 6.1 shows that the DVC tutorials conducted by tutor **B** varied significantly in their word rate. A comparison of the rates for tutorials 1 and 2 where tutor **A** the author and student **C** were very familiar with the system show that the higher rate was consistently for the DVC tutorial demonstrating that the system need not inhibit rates of speech. These results indicate that the dominant restricting factor is unfamiliarity with the equipment.

Analysis of exchange units

Both the DVC and the face-to-face concept centred tutorials (tutorials 6 and 9) were of a virtually identical format to each other. The same was true of the two task centred tutorials (tutorials 7 and 10). The format of the concept tutorial is mainly of the form [**I/R/F**] (see Appendix 4), and for the task centred tutorial a different pattern dominates the structure of the discourse namely [**Inf/F**]. An alternative interpretation of this could be[**R/F**], a response followed by feedback, either the response being by the student to a question previously posed by them or their using the dialogue as a mechanism to obtain feedback and confirmation of their actions from the tutor. This demonstrates that by careful tutor prompting this Socratic dialogue approach i.e. coaxing the student into displaying a supposed knowledge by assuming a pose of ignorance can empower students to answer their own questions. If this interpretation was applied then much of the discourse would have to be considered to consist of ill-formed exchange units, and yet these verbal exchanges play an important part in the learning process for the student. In both of the task centred tutorials the student has done virtually all the writing, modifying their work in response to verbal prompting from the tutor.

The significant difference between concept centred tutorials and task centred tutorials is that the latter involve less dialogue as the emphasis of the session is application of knowledge, irrespective of whether the tutorial is face-to-face or DVC.

The significant difference between concept centred tutorials and task centred tutorials is that the latter involve less dialogue as the emphasis of the session is application of knowledge, irrespective of whether the tutorial is face-to-face or DVC.

Non-verbal input

An inspection of the written work for tutorials 1 and 2, which may be classified as task centred shows that in both tutorials the tutor wrote down questions for the student. With the exception of the writing down of the questions, which was done by the tutor, the work on the whiteboard is far more interactive than it is for the face-to-face tutorial where the student tends to just work through a question provided with verbal feedback from the tutor.

The following two examples are taken from tutorials 1 and 2 and are included to illustrate the more interactive use of the whiteboard as opposed to paper.

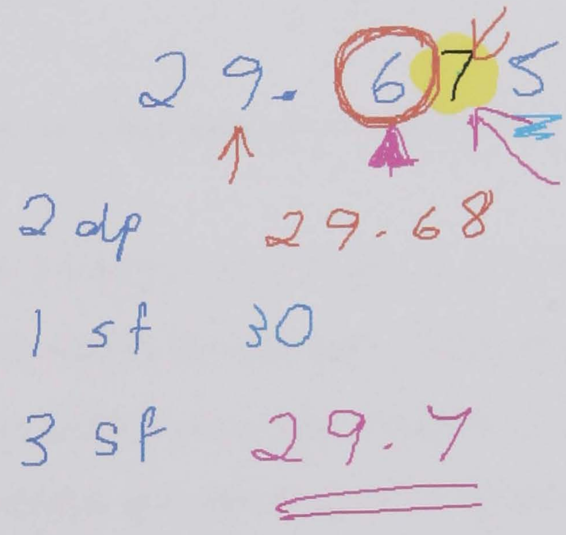


Figure 6.2: Whiteboard from tutorial 1 (DVC)

$$2x \times 4y \times 3x \times 5y$$

$$120x^2y^2$$

$$\underline{2 \times 4 \times 3 \times 5} \times x \times x \times y \times y$$

$$120x^2y^2$$

$$5x - 20 = x + 20$$

$$-x \qquad -x$$

$$4x - 20 = 20$$

$$+20 \qquad +20$$

$$4x = 40$$

$$\frac{40}{4} = 10$$

$$x = 10$$

Figure 6.3: A page from tutorial 2 (face-to-face).

It can be seen in Figure 6.2 that use has been made of arrows, the highlight pen and circling of numbers to provide feedback to the student utilising the different tools available in the whiteboard, i.e. changing the colour of the pen and the highlighter. In tutorials 6 and 7 virtually no use was made of the whiteboard tools other than the eraser. A discussion of the use of the DVC features follows later in this chapter.

In contrast to Figure 6.2, Figure 6.3 illustrates what is typically found in face-to-face tutorials, i.e. the student is either writing the answer to a question or the tutor is writing an example. In each case the written work is being done by only one of the participants at any given time. Figure 6.3 (taken from tutorial 2) is representative of the face-to-face tutorial where the top half is an example written by the tutor, who then writes an equation for the student to solve. The bottom section is the student's solution to the question presented by the tutor.

6.3 Conclusions from the discourse analysis

The rate of verbal discourse is higher for concept centred tutorials than it is for task centred ones. This is not unexpected since in the former the tutor is describing an idea and seeking from the student verbal confirmation that they understand. In the case of task centred tutorials most of the conversation is superfluous, merely the student seeking confirmation of what they are doing or the tutor checking what the student has done, correcting and prompting as required.

The structure of the dialogue is significantly different between concept and task centred tutorials. With the former the exchange units are generally of the form **[I/R/F]**, where the initiation has come from the tutor whereas in the latter most of the dialogue is initiated by the student and is of the form **[Inf/F]** or alternatively **[R/F]**. The length of exchange units also differs between the two types of tutorial, being longer when discussing concepts than when working on tasks.

The whiteboard feature of DVC encourages joint participation by both the tutor and student, as it is an easier medium with which to write collaboratively. The extent to which the participants use the facilities of the whiteboard is, in part, a product of their level of expertise (see section 4.3.5).

The discourse analysis showed that there is differences in the structure of concept centred and task centred tutorials, but no discernable difference in the structure of the dialogue between DVC and face-to-face tutorials were identified. From this we may conclude that DVC tutorials are able to meet the characteristics of the Conversational Framework within a well-structured dialogue, the implication of this being that DVC is a medium that is capable of supporting learning and teaching in a one-to-one situation.

6.4 An assessment of the Modified Conversational Framework

The primary objective in modifying Laurillard's Conversational Framework was to create a research tool capable of recording and analysing the structure of a dialogue for comparison against a set of characteristics. Simple analysis of audio tape recordings of tutorials showed that Laurillard's characteristics were being met. The further analysis was to enable an assessment to be made of how well structured the dialogue was, the criteria used being those of Stubbs' concept of Exchange Units.

In practice, the modified framework did allow a complete analysis of a transcript and was judged to have the following advantages and disadvantages.

Advantages

The analysis, using the modified framework, provides a more complete picture of the tutorial than would otherwise have been possible with Laurillard's original version. As well as providing a more complete picture, this form of analysis, that includes non-verbal communication, makes it easier for a third party, such as a researcher, to interpret the verbal dialogue. The inclusion of the discourse analysis enables an assessment to be made of whether a dialogue was well structured or not, as well as looking for the characteristics identified by Laurillard.

Disadvantages

Producing the transcripts for the analysis was extremely time consuming, although the results obtained justified the time spent. When applying the discourse analysis, distinguishing between exchanges that were initiations and those that were information was difficult, as was defining the boundaries of an exchange unit. The convention adopted was that when the topic of conversation changes a new exchange unit starts. These problems would arise in any discourse analysis undertaken using Stubbs' ideas of exchange classification.

6.5 Use of the whiteboard

For any tutor, using DVC is a more demanding experience than working face-to-face since they have to manage both the tutorial and the DVC software. Understandably, when first using the whiteboard there is a tendency to use it as a substitute for pen and paper. With practice and having developed confidence in using the software it is possible to extend the use of the whiteboard. As Midkiff (2002) identified, DVC has distinct advantages over other systems, as it is an integrated part of the computer. The following series of examples shows how use can be made of the facilities of DVC to enhance tutorials.

Example 1

The first example is a series of images that are intended to show how the whiteboard image can easily be manipulated to illustrate a point. Whilst the initial images can be simply created on paper, modifying them could not be simply achieved.

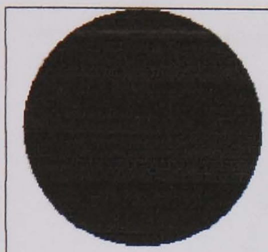
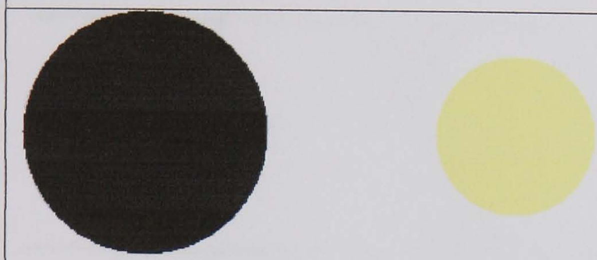
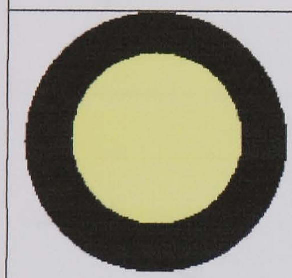
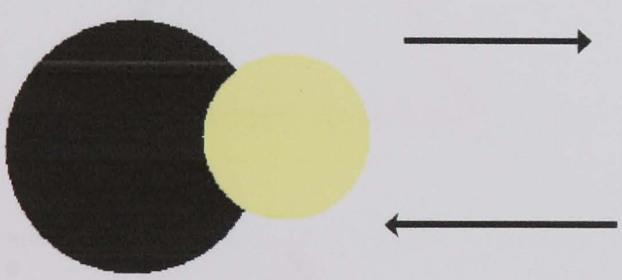
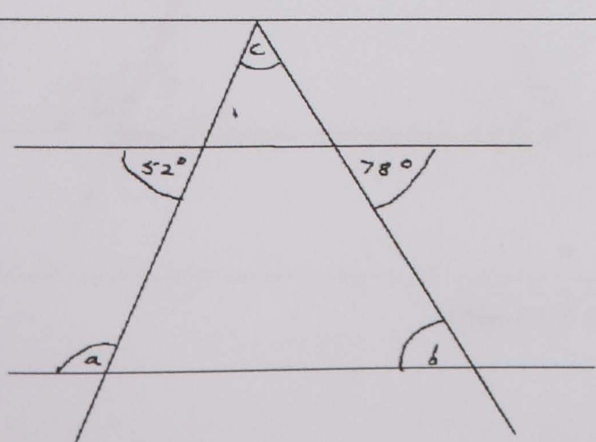
	The student was trying to find the area of cross section of a pipe. A solid circle was introduced and the student was asked to calculate the area, which she was able to do.
	A second circle was introduced to represent the hole and again the student calculated the area.
	The smaller of the two circles was then moved over the larger and the student was asked how she would calculate the black area showing.
	The student couldn't see how to calculate the cross-sectional area, so the smaller circle was moved away and back several times following which the student realised how to carry out the required calculation.

Figure 6.4: An example of the dynamic use of a whiteboard

Example 2

This example illustrates how it is possible to overwrite parts of a diagram.

	The student had been asked to find angles ***a***, ***b***, and *c*.

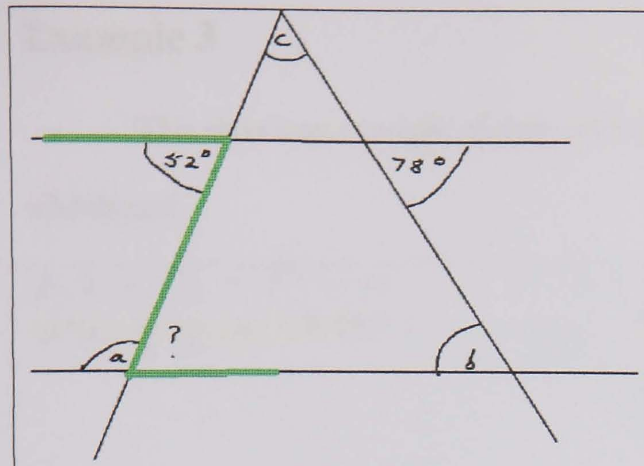
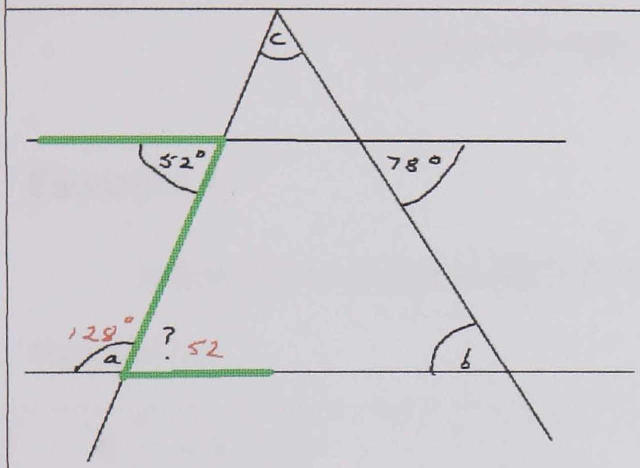
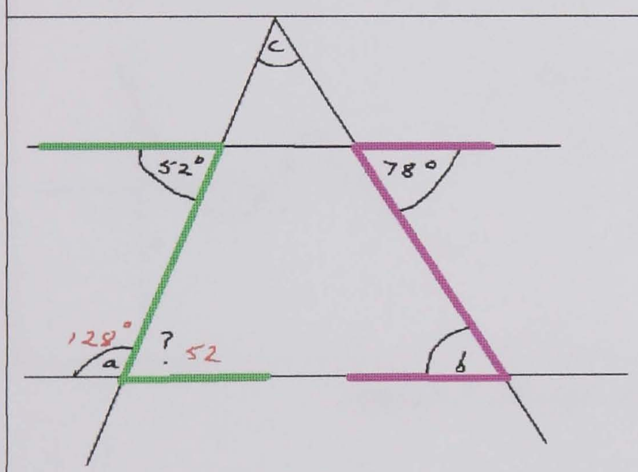
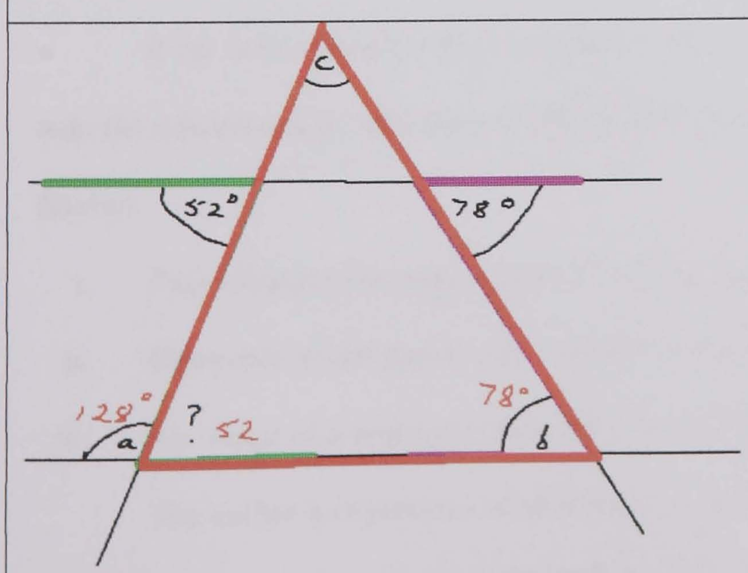
	After the student failed to identify angle ***a*** the tutor highlighted the alternate angle in green.
	Following which the student was able to identify the angle marked ***?*** and subsequently the angle ***a***.
	For angle ***b*** the alternate angle is again highlighted.
	To find angle ***c*** the student has a number of options. To prompt the student the tutor highlighted the large triangle in red.

Figure 6.5: Overwriting a diagram

Example 3

This shows an example of non-verbal feedback using the highlighter facility in the whiteboard.

$4x + 3y = 37 \rightarrow$ $2x + y = 17\ (\times 2)$ $4x + 3y = 37$ $-4x + 2y = 34$ $y = 3$	Here the student had made a mistake multiplying the bottom equation. The tutor highlights this without using verbal communication. The student then corrected the error without further prompting.

Figure 6.6: Example of non-verbal communication

Example 4

Images can be created in other software packages and simply pasted into the whiteboard as illustrated here.

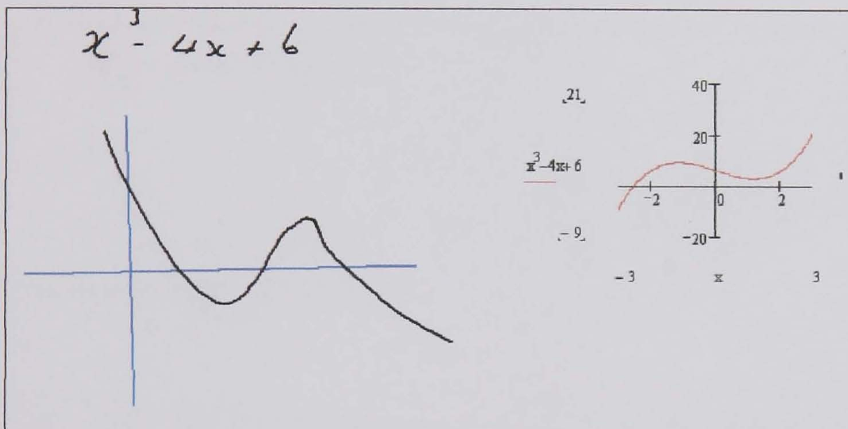


Image created in MathCAD and pasted into whiteboard.

Figure 6.7: Example of adding resource to a whiteboard

It has been found helpful to create the following resources which can be copied and pasted onto the whiteboard as required and which offer the tutor greater flexibility with managing the tutorial:

i. Files of questions organised by topic, including past examination questions.

ii. Electronic graph paper with axes and scales added.

iii. An image of a protractor that can be used for drawing pie charts.

The author's experience of working with the whiteboard over the last four years is that it offers the chance to be more flexible and imaginative in the way concepts and tasks are presented to a student. In addition to the whiteboard it is possible to share files and work on these collaboratively, show video clips and animation, and share with a student any of the facilities available through a computer. A search of the Internet has shown that there are numerous sites offering, for example, animations and illustrations of mathematical concepts. An example of this is Maths Online (accessed 2003), which offers interactive resources on a large range of topics.

6.6 Use of the video image

DVC, by its nature means that non-verbal cues between the participants expressed as body language are lost although the video image does allow facial expressions to be seen. However inspection of the recorded tutorials shows that virtually no use was made of the video image facility other than at the beginning and end of a tutorial. This concurs with the author's experience that the video image is only used during the main part of the tutorial when something unexpected happens, such as a student failing to respond or the presence of a second voice. During the working part of a tutorial both participants are focused on the whiteboard and the accompanying audio discourse. The findings of this study on the use of the video image are in agreement with those of Whittaker (1995) and Reeves & Nass (1996); namely that the audio quality is paramount and that the lack of a continuous video image has little or no effect on the outcome of a tutorial.

6.7 Conclusions

The results reported in this chapter lead to the three main conclusions listed below:

i. DVC is a medium that allows the characteristics of Laurillard's Conversational Framework to be met within a well-structured dialogue.

ii. Where tutorials are of a similar nature (e.g. both task centred), inspection of the detailed transcripts suggests that there is little difference between tutorials conducted face-to-face and those conducted using DVC.

iii. The use of the whiteboard in DVC tutorials allows written material and feedback to be presented to a student in a greater variety of ways than is possible with pen and paper.

The implication of these conclusions is that DVC is a medium that provides no constraints on learning and teaching taking place. Laurillard (1993) takes it as being axiomatic that one-to-one tutorials are the ideal situation for learning and teaching to take place. Since no differences have been identified between face-to-face tutorials and DVC tutorials and since both meet all the characteristics of the conversational framework within a well-structured dialogue it follows that DVC must provide an equally good environment within which learning and teaching can take place. DVC can *'coax students towards an awareness of what it is they fail to grasp...[and provide] description, reflection and feedback'* (Laurillard, 1993).

Chapter 7 Conclusions and implications

7.0 Introduction

The substantial growth in flexible and distributed learning together with the associated need to offer support to students, where appropriate, led the author to ask whether DVC is an effective way to provide this support. The primary aim of this research project was to investigate whether DVC was a suitable medium to deliver one-to-one tuition in mathematics to post sixteen year old students studying mathematics at GCSE, 'A' level or IB. Laurillard's (1993) analysis of media (which did not include DVC) concluded that none of the media available at that time was able to support all the characteristics that she considered necessary for teaching and learning to take place. The number of characteristics that need to be met will depend on the nature of the tutorial. For example, if the tutorial is purely concept centred then characteristics 1 to 4 need to be met. In the event that not all of the applicable characteristics are met then by implication this will have an effect on the learning outcome. In Laurillard (2002) a brief mention is made of DVC, but she does not attempt to analyse its potential as a medium for learning and teaching.

The strategy adopted by the author to evaluate the effectiveness of DVC was to compare both the structure of the tutorials and the learning outcomes of students receiving their support using DVC with that of students receiving their support through face-to-face tutorials.

The two research questions detailed in Chapter 3 sought to establish:

i. Whether it was possible to measure, or predict the improvement in a student's performance as a result of receiving learning support.

ii. Whether, given that a student is receiving learning support, there is any difference in learning outcomes between the two forms of tutorial.

The criterion which was to be used to measure learning outcome for a student was the score achieved by them in the mock examination which they sat prior to their GCSE examination in mathematics. The mock examination results were used because the examination board were not prepared to release the students' actual marks to the author. The mock examination paper used in each of the three years was the previous year's GCSE paper. It must be acknowledged that there may have been some variation in the level of demand of the actual examination papers; however in the absence of a large database of results no moderation of the marks was attempted.

During the early stages of the study the emphasis was on the collection of statistical data. However the need to broaden the research soon became apparent due to the limited nature of the statistical results when applied to sociological research. A simple comparison of statistical results, such as would be required to answer the questions above, would mask or fail to identify much of what else was being learnt through the study. For example, the students' attitude towards DVC tutorials could not be measured on a parametric scale and hence could not be included as one of the variates in the regression analysis. In particular, relying purely on a statistical approach would fail to identify the similarities, differences and potential benefits of the two forms of tutorial. Further much of what was being learnt about how to make best use of DVC would not be revealed by a statistical analysis.

To address these issues the scope of the research was widened to include an analysis of both face-to-face and DVC tutorials to determine whether the characteristics of Laurillard's Conversational Framework were being met within a well-structured discourse. The analysis of the tutorials was done using the modified Conversation Framework detailed in Chapter 3.3, which includes the basic idea of discourse analysis and in particular Stubbs' (1983) idea of an exchange unit, which may be either well or ill-formed in structure. This analysis then allowed a comparison to be made between the two forms of tutorial, which showed that no identifiable differences could be found between the two forms of tutorial. Further, interviews and questionnaires, which were used extensively throughout the course of the study, were used to identify the similarities and differences between:

a. DVC and face-to-face tutorials.

b. The tutors' and students' perceptions and impressions of the outcomes of the tutorials.

c. Features and advantages, which are unique to DVC.

This chapter concludes with a consideration of which of the outcomes of the study can be generalised and possible areas for further research into the use of DVC.

To draw together the findings from the three strands of the study (statistical, questionnaires and discourse analysis), the author has posed a number of questions and summarises the evidence produced by the study to answer them.

7.1 Is the outcome (defined as the result in a student's mock examination) for students receiving learning support, significantly different to that for those not receiving support?

Inspection of the results in Table 5.1 shows that 56.6% of the students receiving support improved their GCSE grade compared to 59% of those students not receiving support. However if the retention rates of students on the course are included then the results show a different picture. Since the retention rate is higher for the group of students receiving learning support, we then obtain the following figures. For the students starting the GCSE mathematics course, 23.7% of those receiving learning support improved their grade compared to only 16.5% of students who did not receive learning support.

The regression analysis for all students (see Table 5.11) shows that the level at which a student previously studied GCSE mathematics was statistically very close to being a significant factor (where the coefficient is greater than twice the standard error). On the other hand, for those students who had received learning support (Table 5.15) the level at which they previously sat GCSE mathematics was not a significant factor. This suggests that the initial disadvantage experienced by those students who previously only studied GCSE mathematics at Foundation level, and thus had not studied the complete syllabus, was mitigated by the provision of learning support.

The improvement in retention rates amongst students receiving learning support (Figure 5.1) is in line with other research (Basic Skills Agency, 1997). The very high retention rate of over 80%, amongst students receiving support-using DVC, was an important observation. However, this could be due to a number of other factors including the realisation of the students that they formed part of a research project and their wish to be cooperative. In contrast the results of the questionnaires (section

4.1) showed that all students, with one exception, preferred DVC to face-to-face tutorials. Whilst no firm conclusions can be drawn from these results it seems plausible that the DVC experience did contribute to the higher retention rate of students.

From this study it would seem reasonable to conclude that one-to-one learning support does improve the retention rate of students. On the other hand, while retention rates are improved, learning support does not appear to improve students' performances but rather mitigates the disadvantages with which some students started the course. In particular learning support is thought to benefit those students who had previously studied GCSE mathematics at Foundation level.

7.2 Is the learning outcome, for students receiving learning support using DVC, significantly different to those receiving support face-to-face?

Appendix 7 shows the outcomes for students included in the study. These results show that all students who received support through DVC improved their outcome by at least one grade, whilst the same is not true for those students who received support through face-to-face tutorials. Whilst a number of factors could have affected the outcome this result does suggest that DVC is at least as good as working face-to-face.

A detailed analysis of tutorials 6,7,9 and 10 (Table 6.1) was conducted using the modified Conversation Framework (see chapter 3 section 3.4). This was possible because of the way in which the tutorials were recorded. The discourse analysis of parts of these tutorials included in section 6.2 suggests that there are no identifiable differences between the two types of tutorial. Both types of tutorial allow all of the observable characteristics of Laurillard's Framework to be met within a well-structured dialogue. The inference from this is that both can achieve similar learning outcomes.

A partial analysis was made of tutorials 1-5. It was found that without including the non-verbal discourse in the analysis the dialogue appeared to have a large number of ill-formed exchange units suggesting that the tutorial was not conducted within a well-structured dialogue. This result was more a product of the method rather than poor dialogue (see Chapter 3 section 3.4 for further discussion of the problems of analysing audio only transcripts). The number of the characteristics met in any particular tutorial depended on the nature of the tutorial; all those required by the Conversational Framework were met.

The results from questionnaire 2 (section 4.12) suggest that there is no significant difference between the two forms of tutorial based on the students' and tutors' perception of how well the characteristics of the Conversational Framework were met, with the possible exception of the feedback from tutors where DVC seems to have an advantage. This is probably due to the tutor having a clear view of what a student is writing at all times; thus giving more time to reflect on the student's work rather than having to look at the completed answer. Since both forms of tutorial do equally well in satisfying the characteristics of Laurillard's Framework this implies that the learning outcomes for both can be similar.

The regression analysis (section 5.3) conducted on the data for students receiving learning support provides further evidence to suggest there is no significant difference between DVC tutorials and face-to-face tutorials. This conclusion is drawn on the basis that the two types of tutorial are not differentiated in the analysis, and since a very high correlation coefficient was obtained (0.91), this suggests that there is little difference between the two in terms of outcome.

In conclusion the evidence provided by this study suggests that there is no apparent difference in outcomes from the two forms of tutorial.

7.3 Is the experience of students receiving learning support using DVC different to those receiving support face-to-face?

Whilst the learning outcome from the two types of tutorial may not differ, the experience of the students is noticeably different. Results from the questionnaires and interviews show that students preferred tutorials using DVC to those conducted face-to face. This suggests that from the students' perspective there must be some substantive differences between the two types of tutorial. This argument becomes more compelling given that several of the students included in the study had received learning support through both types of tutorial.

7.3.1 Differences identified by the study and possible explanations for them

Students found DVC tutorials less stressful and less intense and felt they were under less pressure than when sitting next to a tutor. The distance from the tutor reduced the pressure students perceived themselves to be under and this in turn created a more relaxed atmosphere for the student. This reduction in stress, amongst the students using DVC, which has not been previously reported, is considered to be a significant benefit of using DVC.

It is the opinion of the author, based on consideration of both the rate of verbal discourse and inspection of written work from the tutorials that at least as much work, if not more, was done during the DVC tutorials compared to the face-to-face tutorials.

The electronic whiteboard in Netmeeting has distinct advantages over paper. Both participants have a clear uninterrupted view of the screen and hence the electronic whiteboard. This means that both participants can see what the other is writing, thus affording the tutor the opportunity to give more rapid feedback to a student than would normally be possible. Parts of the work can be highlighted, for example to identify alternate angles in a diagram where as in a face-to-face tutorial this could only be achieved with both participants standing in front of a blackboard or conventional whiteboard. The easily used tools in the whiteboard mean that errors can easily be corrected and the colour and width of the pen can be changed. When necessary, the construction of diagrams is considerably easier and both parties have unobstructed views of the emerging diagram. It is also possible to zoom into parts of the whiteboard enabling closer inspection of diagrams, graphs etc. This was found to be particularly useful with students such as the visually impaired student mentioned in chapter 4.2.

7.3.2 The effects of whiteboard use on the conduct of a tutorial

The advantages of the whiteboard identified in section 7.3.1 have a number of effects on the conduct of a tutorial.

One of the key areas was with regard to feedback. Tutors can provide quicker feedback to students if appropriate. Feedback given by the tutors can be more variable in nature with more scope for providing non-verbal feedback than would normally be possible in a face-to-face tutorial, for example highlighting an error rather than telling the student.

The other key area was the visibility of the working being carried out on the whiteboard. Since both participants have a clear view of the whiteboard at all times it is easier for both of them to see the construction of an argument and the students' responses as the argument progresses.

7.3.3 Other advantages of DVC

The retention rate amongst students receiving learning support through DVC was significantly higher than for students receiving learning support face-to-face. This may be a result of the students working within a learning environment that they found enjoyable.

The environment of DVC leads to a more focused working atmosphere. In part this is thought to be a consequence of the student being unable to refer back to previous questions on earlier whiteboards (without the tutor being aware), and in part because the student is unable to anticipate when and what the tutor is going to write on the whiteboard next. There is some evidence from the questionnaires and interviews that there are fewer distractions for the student, due in part, to the fact that the students are using headphones, thereby reducing background noise.

To summarise, this project has found no evidence to suggest that DVC is in any way an inferior learning environment to traditional face-to-face tutorials. On the contrary it has identified positive benefits from its use.

7.4 What can be generalised from the research?

Laurillard's Conversational Framework is taken to be applicable to any subject where learning and teaching requires intellectual application. This research has shown that DVC is able to satisfy the characteristics when used for mathematics (at Key Skills level 1, 2 and 3), within a well-structured discourse. Since the use of DVC can overcome many of the notational difficulties experienced with mathematics it is a suitable medium to deliver support for any subject at those levels. There is also a growing body of research literature (Jennings *et al.*, (1998), Hearnshaw, (1997), UCL (2002)), which concludes that DVC can successfully be used in higher education.

7.5 Other outcomes from the research

The modified framework provides a tool for analysis of both the verbal and non-verbal dialogue that takes place in a tutorial. Whilst Laurillard's framework has been taken as a model for this study, the analysis shows that a significant part of the dialogue cannot be classified using the characteristics she specifies. This in itself does not imply that there are characteristics missing in the framework but rather that there are events occurring within the discourse which may or may not contribute to the learning outcome. For example, a student may ask the tutor if what they have done is correct; this action cannot be classified under any of the characteristics of Laurillard's framework. Thus, whilst a dialogue that satisfies the characteristics of the Conversational Framework may be deemed to provide a suitable environment within which learning and teaching can take place, the framework in itself does not provide an adequate tool to analyse the discourse.

7.6 Areas for further research

1) **The use of DVC with specific groups of students**

Observation of a large number of students by the author over the last decade suggests that DVC may be particularly suitable for two types of students, the first group would be students with specific visual impairments and the second would be those with attention span problems.

One such student could not see print or written work clearly unless it was against a green background. However working with a computer monitor presented no problems for him. The whiteboard also had the advantage that an image could be enlarged. This helped him to see fine detail, in, for example, geometric diagrams.

The second group are students suffering from acute attention deficiencies or disruptive tendencies in a classroom situation. Observation by the author and Ruthven and Hennessy (2002) suggests that such students are more focused when working with a computer than they are in a classroom situation.

2) **The age range of students that can successfully use DVC**

In this study the ages of the students using DVC ranged from 16 to 40+. Sixteen is the lowest age for which the author is aware of DVC being successfully used which poses the question can it successfully be used with even younger students? If it can, its application may then be appropriate to students who have been excluded from school or those who are unable to attend due to illness.

3) **Does using DVC improve retention rates amongst students receiving learning support?**

The retention rate amongst students using DVC in this study was higher than would normally be expected from GCSE retake students. Further investigation could question whether this was exclusively due to the use of DVC or if other factors played a part. Also, attempts could be made to replicate this result with a larger student sample and a number of different tutors.

4) **How does learning support affect students' confidence with, and attitude towards, mathematics?**

This study shows that the improvement in learning outcome for weaker students (or possibly those that had previously underachieved at school) was greater than amongst re-sit students in general. Learning support tutors generally acknowledge the importance of improving students' confidence in their own abilities and trying to instil in them a more positive attitude to their studies. The question then would be, how significant a factor is a student's self-confidence in successfully completing a course?

5) **How best to train people to use DVC?**

Clearly for both tutor and student there is a confidence building process when first using DVC. As the tutor in particular becomes more confident with the use of the software and its potential benefits and limitations, it is possible to extend the ways in which the features of the software, such as highlighting, are used. The issue then is how best to pass on this knowledge to inexperienced tutors. One of the ways identified during the course of the study was the use of electronic resource files containing such items as questions, graph paper and animations to demonstrate transformations. The effectiveness of tutors using these files could then be compared with tutors who were not.

6) **Further applications for the modified framework**

The tool developed for the analysis of tutorials has been found to work well in practice despite the fact that it is slow to analyse a dialogue. The author can see no reason why it should not be used to analyse any one-to-one dialogue between student and tutor or even between a tutor and a group of students and might also be suitable for identifying problems experienced by specific student groups, e.g. student teachers. As voice recognition software becomes more accurate it will become increasingly easier to produce accurate transcripts of the verbal part of a tutorial. This would greatly speed up analysis using the modified framework.

7.7 Personal reflections on the use of DVC

After four years of using DVC to give learning support to students at Exeter College the question the author would pose to himself is "Does he wish to continue using DVC?" The answer to this is unreservedly "yes". Students like this form of tutorial as it provides a relaxed and focused environment in which to work. The author's subjective view is that students get more out of DVC tutorials than they do from a face-to-face one. This way of working allows the author to make better use of his time by eliminating travel. There is also the benefit that in the event of a student failing to keep an appointment for a tutorial, the tutor can quickly turn to other work, most of which is computer based. In the context of working at Exeter College, working face-to-face with students in the Study Centre does not allow the same degree of flexibility as the tutor would not be in his / her normal working environment.

Over the period of this study the author had envisaged that there would be a substantial increase in the use of DVC. To date this has not materialised, due, it is thought primarily to difficulties experienced with connectivity, particularly through networks where firewalls are being used. The problems seem to be due to the Netmeeting software using dynamic ports for the audio. At Exeter University for example, in all three locations where DVC is being used the method of connection is using ISDN telephone lines because of difficulties experienced with network connections. Using broadband to connect between computers avoids these problems and is seen by the author as the likely area of development. Two recent developments seem to support this. The first is that Microsoft's latest version of Windows XP includes a firewall designed specifically to allow Netmeeting through it. The second is the Prime Minister's pledge in October 2004 of "*Bringing broadband to every home and investment in the knowledge economy*" (BBC, 2004). The author is optimistic that the use of this technology will increase as, for example international connections can be made at no cost other than the monthly fixed charge for the line rental.

It is believed that this study will go some way to eliminating any pedagogical objections to the use of DVC in education.

Appendix 1

TEACHING MATHEMATICS AND ITS APPLICATIONS Volume 19, No. 4, 2000 173

A Report on Experiences of Using Desktop Video Conferencing in Mathematics

BRIAN WALKER AND TED GRAHAM

Submitted May 2000, *accepted* September 2000

Abstract

This paper reports on the results of an experiment to investigate the use of desk top video conferencing (DVC) to provide one to one tutorial support in mathematics. The paper describes how the equipment has been used and provides examples from some of the sessions that have taken place. The authors then outline the potential advantages and disadvantages of DVC in this context.

Introduction

THE WORK described in this report is part of a broader study of the problem of providing individual tutorial support for distance learners, which involves the use of modern communications technology. In September 1999, with the cooperation of Exeter College, work was started to evaluate the effectiveness of Desktop Video Conferencing (DVC) as an appropriate communication tool. In this study DVC is being used as an alternative to traditional methods to provide learning support for a proportion of the students re-sitting GCSE mathematics at the college. At present, students study in a "workshop" environment under the direction of tutors with supporting lectures on key topics. Students may be referred for one-to-one learning support where it is considered appropriate. The motivation for the study is supported by Hearnshaw (1997) who suggests "little is known about the relationship between the quality of a videoconference and its impact on educational outcomes".

What is Desktop Video Conferencing (DVC)?

DVC is a technique, which allows two or more persons in different locations to communicate live, or synchronously, using computers, which are linked together. The link is such as to allow both live audio and live video to be simultaneously transmitted between those participating in the same way as a live news report on television allows a reporter to both talk to and be seen by the presenter, in the studio, and vice versa. Using such methods also makes it possible to transfer computer files between the participants and to enable them to read and process them on a shared basis. DVC is possible with any reasonably modern personal computer fitted with an inexpensive video camera and which has a means of linking to other computers. Such links can be achieved through dedicated computer networks (local, national or international) or telephone lines, using a high-speed modem. The quality of communication is improved by using dedicated ISDN telephone lines. Adjuncts to communication include e-mail links and the Internet. The effectiveness of these varies considerably, depending on the speed and capacity of the server being used and the volume of "traffic". DVC can be used between a number of participants; Hearnshaw (1997) used it in the ratio of 1:4 to provide tutorial support to students on an IT course. However Wright and Cordeaux (1996) have concluded that the best use of this technology (DVC) is in situations where communication is "one to one".

DVC should be distinguished from conventional videoconferencing, which is typically delivered "one-to-many" (e.g. a lecture given in the University of Plymouth transmitted to student nurses in a number of locations throughout the Southwest) or "many-to-many" (e.g. the Royal Bank of Scotland using video conferencing to avoid executives travelling to meetings). Both of these are relatively expensive compared to DVC and may require the use of recording studios and satellite links to achieve an acceptable quality of transmission. DVC should also be distinguished from videophone links, which only offer audio and simple video images and lack the extended range of facilities available with DVC.

Why use DVC?

The predicted growth of flexible and distributed learning at both FE and HE levels throughout Europe, will inevitably lead to increased demands for learning support. The FEFC consultative strategy document entitled "Networking Lifelong Learning" includes a government target to

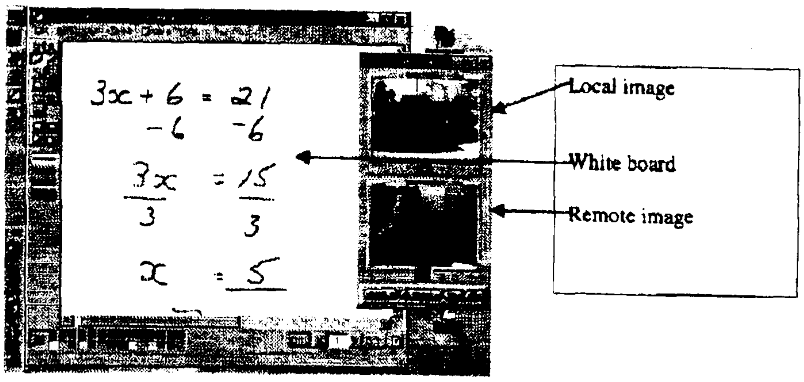


Fig. 1. The general arrangement of the screen

increase the number of students in FE by 700 000 by the year 2002. There is also emerging evidence that private companies are moving towards buying-in training, particularly at a postgraduate level, to meet their specialist training needs; web based materials being seen as offering the flexibility required.

In addition to the traditional methods of providing learner support, the new technologies, now widely available, offer additional modes of delivery e.g. e-mail, Computer Conferencing, and Desktop Video Conferencing (DVC). It is estimated that there are currently 50 million households in Europe with access to the Internet, this figure is expected to rise to 80 million within five years.

Whilst all methods of learner support have a place, the medium offering the most flexibility and potential for one-to-one tutorials in mathematics is seen by the present authors as being DVC since this allows interactive communication and the ability to write mathematical notation in a traditional way using a pen. One clear advantage of DVC over the other forms of communication is that it is synchronous. One limitation of the use of DVC at present is the cost of ISDN connections. It is expected that cost will reduce substantially over the next few years with the introduction of "wireless" communication and increased competition.

DVC is seen as a potentially effective way of delivering one-to-one tutorial support to students who are unable to gain face-to-face contact with a tutor and is viewed as being particularly useful for students in employment, offering the possibility of tutorials within working hours at the work place.

What equipment is needed?

At the lowest effective level of implementation, DVC requires the following:

1. A personal computer linked to a communications network - typically this will either be a local area network (LAN) or implemented using a telephone link such as an ISDN line.
2. A DVC implementation package, comprising a p.c.card, software, video camera and a headset (or speakers and a microphone). Microsoft Windows 98.2 incorporates an updated version of a software product called "Netmeeting", which requires only a simple video camera as additional hardware. This represents a potential saving of over £400 on the cost of equipment hitherto required.
3. A Graphic Tablet. This is a device that replicates the action of a "mouse" and allows hand writing and drawing directly into the computer using a "pen" facility with appropriate drawing software.

How it works

A connection between the two computers is made in a similar way to a telephone call using a preprogrammed number. Once the connection has been established both video and audio links are initiated between the participants. A screen like that shown in Figure 1 appears, when the system is started up.

The size of the video images can be adjusted up to full screen size for the receiving participant. Once the goals for the session have been set, the authors have found it most useful to enlarge the whiteboard to fill the whole screen giving the maximum area in which to work. This approach has been corroborated by Wright and Cordeaux (1996) who note "Our experience has suggested that the technology can facilitate an approach to learning if preoccupation with the video aspect does not assume primacy as this distracts from moving on into working collaboratively using the data services. The video is useful to establish human contact, create reassurance and assure 'visible' support, but once work begins on an issue or a document the video assumes far less importance".

The whiteboard can be minimised at any point if it is thought beneficial to restore the video images. The whiteboard incorporates features that would be difficult to replicate in a normal one-to-one tutorial including: having a large variety of colours for the pen and highlighter, an electronic pointer that can be moved by either participant, easy correction of errors and a capacity to draw diagrams. It is also possible to access files, which provide questions for students to work on. One of the exciting features of the whiteboard is that a student cannot anticipate what the tutor is next going to put on the screen.

The whiteboards available to both sender and receiver are synchronized, which means that the participants see the same area of the board and are able to write simultaneously, each seeing the other's work. This has the inherent advantage that the tutor can see exactly what the student is writing and the speed at which he/she is working.

A typical DVC tutorial

Students at Exeter College re-sitting GCSE mathematics study mainly from "modules" written by the staff. Good practice therefore dictates that learning support tutors follow closely the methods explained in the printed modules.

The following images were captured during the first two tutorial sessions, (each of one hour), with a student Jamie.

Jamie wants to join the fire service (which requires a grade C at GCSE mathematics) after completing two A-levels at the College. He achieved a grade D at foundation level in his GCSE, which he sat in June 1999. In the "initial assessment test" taken at the beginning of the course at the College he achieved an average score for "potential" and below average for the "numeracy" test, which suggests under achievement at his previous school.

The goal for the tutorials was the solution of simple linear equations, taking the topic as far as the student was able within the syllabus. Having tested Jamie's prior knowledge, first by asking him to solve equations where the answers were whole numbers and then by introducing questions where the answers were fractions, it was apparent that he was trying to solve equations on a trial and error basis by finding numbers that fitted. Having discussed with him the need for a systematic approach, which would work for any equation, an algorithm was constructed in stages for tackling these types of equation. All writing by Jamie is in black the other colours being used by the tutor.

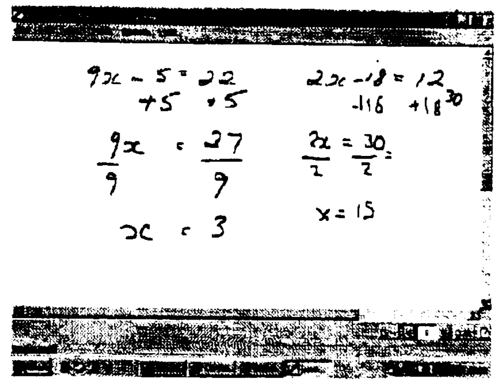


Fig. 2. First steps in solving linear equations

The whiteboard reproduced in Figure 2 is the first example shown to the student, the question on the left being done by the tutor, that on the right by Jamie. This represents the last two stages of the three-stage algorithm, which it is being developed. That is "getting rid" of any number on the side of the equation where the X's are and then dividing by the number in front of the X. The notation used is to emphasise that the same operation must be applied to both sides of the equation.

After Jamie had solved the equation on the right a new white board was put up with a new question; this means that he cannot see the example that he has just completed and must rely on what he has retained to answer.

A new whiteboard was put up this meant that Jamie could no longer see the previous examples; he then solved a number of further examples relying on the knowledge he had retained. Figure 3 below shows the students working.

Having successfully completed a number of examples, equations with "X" on both sides were introduced.

Figure 4 shows the final stage of the algorithm. The equation now has X's on both sides, the strategy is now to "get rid of the smallest number of Xs" without worrying about which side of the

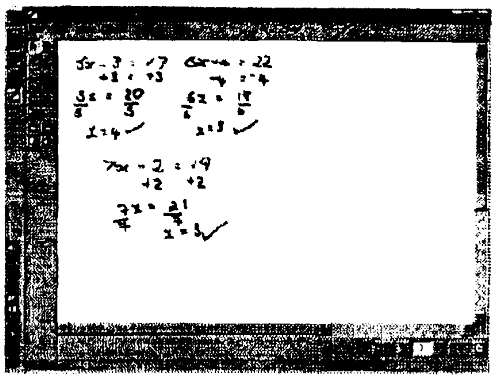


Fig. 3. Examples of additional questions answered by the student

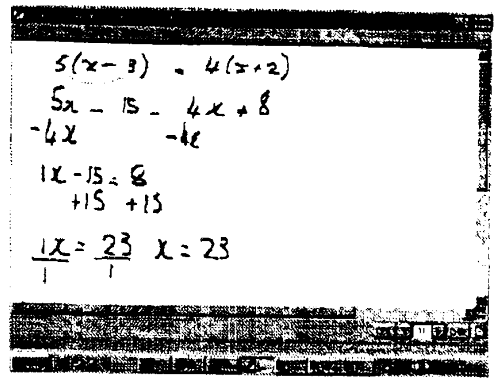


Fig. 5. Removing brackets

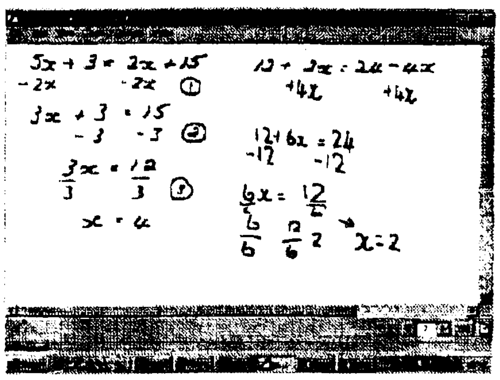


Fig. 4. The final step in solving an equation

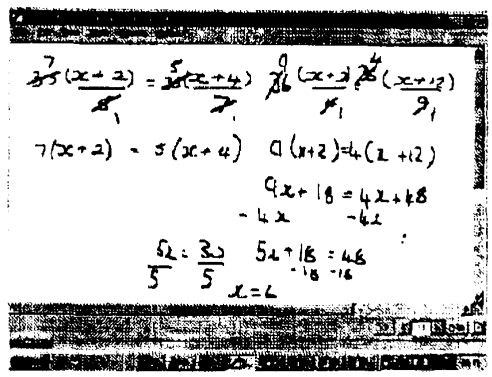


Fig. 6. Removing fractions

equation the X's are on. The example on the left was completed by the tutor and the one the right by Jamie. The circled numbers identify the three steps necessary to solve an equation of this type and had been discussed with Jamie as he worked through examples.

Attention now turned to what might be required before the equation could be solved. The strategy here was to remove any brackets/fractions and simplify the equation if necessary before starting to solve it.

First the problem of removing any brackets was tackled. Figure 5 shows how the tutor can prompt and correct the students work if necessary (on the screen a different colour is used).

Finally fractions were introduced, again with the strategy of first removing them as a preliminary to solution. In Fig. 6 below the left is an example done by the tutor showing how the fraction can be removed by multiplying by the product of the denominator (without considering the LCM).

The outcome of these two sessions was as good, if not better than, than that which would have been expected from a student with Jamie's mathematics background using conventional methods. The session that followed recapped on what had been covered in the previous session and then moved on to the solution of simultaneous equations, which again presented no great difficulties to him.

Advantages

1. The whiteboard gives the tutor a potentially powerful new tool to assist in the assessment of a student's understanding and ability to tackle problems. The authors feel that this approach can be more effective than when

simply sitting next to a student, because of the more interactive and intense environment that it creates.

The whiteboard also allows a much more interactive and collaborative form of tutorial, with the tutor being able to modify or highlight any part of the board at will. (e.g. the tutor can highlight the place at which a student has made a mistake and then wait for the student to realize the significance of the tutor's action). Corrections can easily be made. This has been found to be particularly effective with problems involving "shape and space".

Images can be imported from additional electronic files thus allowing the tutor to use pre-prepared facilities or materials, e.g. graph paper or a set of equations to solve. At present a library of such files is being built up. Students' work can be saved as a file for future reference and can also be printed out if the student wishes to keep a record of the work covered.

2. The overall impression gained to date is that DVC is a more intense experience than normal tutoring, a high degree of concentration being required on the part of both the student and the tutor. The student must concentrate more than usual as they are unable to see the earlier whiteboards; this must have definite pedagogical advantages and may lead to better "relational understanding" Skemp (1976) of the topic, it tends to discourage rote type learning. The tutor has to work harder because they have to concentrate on both the student and the technology.

   Tutorials are very focused with little potential for the students to get distracted; there is also a lack of the usual social discourse, a conscious effort being needed to introduce this at times in order to "lighten" the session. Jennings et al (1998) found, during the use of DVC, that "the act of pointing and highlighting demanded by the technology provoked more attention to detail. This in itself made the video conference really exhausting and intensive". It may be that tutorials could be shortened with no loss of outcome when compared to face-to-face tutorials.

3. The equipment, generally, has been well accepted by the students; some seem to positively enjoy the new technology, the use of which is seen as a transferable skill. Where technical problems have been experienced they have been accepted with good humour and students have co-operated in solving them. Overall the present authors would describe the attitude of students to the new learning experience as being positive.

Disadvantages

1. The level of "computer literacy" amongst students was lower than had been expected, despite the software being extremely simple to use. A preliminary training session of around 20 minutes has been found to be useful and this can be conducted through the video link.
2. Many unforeseen software problems have been experienced while using the electronic whiteboard. (e.g. the use of the eraser function has been found to cause disconnection of the meeting). The whiteboard facility forms part of the "Netmeeting" software, its use has so far been limited to straightforward tasks to avoid problems. Version 2.11 of Netmeeting has recently been installed and it is hoped that this will prove to be more robust. Fortunately, free updates of the software are available over the World Wide Web.

   Some problems can result from the actions of the students. These can be controlled to a large extent by assuring that the boards on the two PCs are fully synchronized and that overall control resides with the tutor. Thus, at the outset, a protocol needs to be established with the student for the operation of the whiteboard such that control rests solely with the tutor unless the student has adequate technical competence.
3. DVC is unable to offer the flexibility of face-to-face tutorials. Since one cannot be sure of having copies of the materials to hand that the student is working from, more preliminary planning is required. For example, where a student has been working on a past exam paper and wants to discuss a particular question, transmission of that question to the tutor may be problematic and time consuming and needs to be done in advance. For instance, a diagram in a question involving reflection or rotation would take the student some time to reproduce "live" on the whiteboard and would be difficult to perform accurately. The transmission of a pre-scanned version of the diagram would assist the process. Jennings et al (1998) have identified the need for detailed planning of sessions where DVC had been used for tutorial support of student teachers on teaching practice.

4. Certain topics such as geometrical translation are difficult to illustrate on a whiteboard; however in the longer term, draughting software packages, which incorporate the functions of reflection, rotation and translation could be employed to solve such problems.

Conclusions

Are the students gaining as much as they would from normal tutorials? The present authors believes so and in the case of some students progress to-date has been much better than would be anticipated based on past experience.

For example Sarah, a GNVQ Art and Design student, came to the College with an E in GCSE mathematics and the considered opinion that she "hated maths". At the end of a one-hour tutorial, the electronic whiteboard session had covered some revision on directed numbers and she had learnt to solve equations with the variable on both sides, e.g. $(5 + x = 17 - 5x)$. The student's reaction at the end of the session was "I wouldn't have believed that I could have done that".

Early indications are that DVC is an effective alternative to traditional tutorials, whilst at the same time providing a challenging new medium for presenting ideas and concepts using the whiteboard. The authors agrees with Jennings et al (1998) in that "video conferencing makes a more powerful contribution to students' learning than merely replacing a face-to-face conference".

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Brian Walker currently lectures at the University of Exeter and and Exeter College. He gained an Open University mathematics degree in 1975. He worked for many years in the construction industry, before signing up for a PGCE course at the University of Exeter in 1994. Since then his interest in the teaching of mathematics has developed to include the use of DVC. Brian is currently working towards a research degree with the Centre for Teaching Mathematics at the University of Plymouth.

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Appendix 2

Appendix 2.1 – Initial Questionnaire

Desktop Video Conferencing DVC

Name... date...........................

I would like to get your early impressions of DVC. Can you please complete the Questionnaire below

1) How easy did you find it to operate the equipment

2) List the things you don't like about DVC

3) List the things you do like about DVC

4) any other comments

Appendix 2.1.1 Results of Initial Questionnaire

Table 1 - Question 1 "How easy did you find it to operate the equipment?"

Key word/phrase	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Easy or very easy	✔	✔	✔	✔	✔	✔		✔	✔	✔	✔		✔	✔	✔	✔		✔	✔	✔			✔	✔	
Reasonably/ Quite/fairly easy							✔					✔					✔				✔	✔			✔
Quicker/easier using the pen rather than a mouse	✔																								

Table 2 - Question 2 "List the things you don't like about DVC"

Key word/phrase	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Technical problems	✔					✔																			
Camera			✔																						
Headset not comfortable							✔			✔	✔														
Echo											✔		✔												
Not seeing tutor all the time															✔										
Slowness in showing other person what you have written																	✔								
Not knowing how to look back at questions																		✔							
A little distracting																				✔					
Seeing myself on the screen																					✔				
More difficult to talk																								✔	
The pen																									✔
No comment		✔		✔	✔			✔	✔			✔		✔		✔			✔		✔		✔		

Table 3 Question 3 "List the things you like about DVC"

Key word/phrase	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
User friendly	✔		✔							✔															
Easy to hear		✔				✔																			
Relaxed less stressful being alone				✔	✔					✔		✔													
Enjoyable/fun							✔	✔	✔								✔			✔			✔		
New/novel											✔														
No paper													✔												
Everything														✔											
Flexibility of location															✔										
Not seeing all the questions																	✔								
Easy corrections by Tutor																		✔							
More challenging, adds excitement																									✔
Easy to write																		✔							
The DVC package																✔									
Easier to work this way																			✔						
Learnt a lot																				✔					
Highlight pen																								✔	

Student Questionnaire

Tutor...............
Date..................
Day: mon, tues, wed, thurs, fri
Start time.....................
Duration.................... DVC yes no

5 = strongly agree
4 = agree
3 = not sure
2 = disagree
1 = strongly disagree

Please ring one option below

1 The aims of the lesson were clear to me	5 4 3 2 1
1a) The aims of the lesson met my needs	5 4 3 2 1
2 I was able to explain myself clearly to the tutor.	5 4 3 2 1
3 The tutor was able to explain to me what I needed to know	5 4 3 2 1
3a) Examples given by the tutor were clear	5 4 3 2 1
4 I understood the tasks and the questions that the tutor wanted me to carry out	5 4 3 2 1
5 I was able to think about where I had gone wrong	5 4 3 2 1
5a) The tutor was able to help me see the way forward.	5 4 3 2 1
6 The questions set by the tutor were clear and challenging	5 4 3 2 1
7 The tutor was well organised	5 4 3 2 1

Comments

Tutor Questionnaire

student...............
Date..................
Day: mon, tues, wed, thurs, fri
Start time.....................
Duration.................... DVC yes no

5 = strongly agree
4 = agree
3 = not sure
2 = disagree
1 = strongly disagree

Please ring one option below

1 I was able to set clear aims for the tutorial.	5	4	3	2	1
1a) The aims of the tutorial met the needs of the student.	5	4	3	2	1
2 I was able to adapt tasks set for the student in the light of the students understanding and actions.	5	4	3	2	1
3 I was able to describe required concepts to the student	5	4	3	2	1
3a) I was able to provide suitable examples for the student	5	4	3	2	1
4 I was able to provide suitable questions for the student	5	4	3	2	1
5 I was able to reflect on students actions to provide feedback	5	4	3	2	1
5a) I was able to give student feedback on tasks carried out by them.	5	4	3	2	1
6 The questions I set for the student were challenging	5	4	3	2	1
7 I was well prepared for the tutorial	5	4	3	2	1

Comments

Appendix 2.3

Desktop Video Conferencing (DVC) -Final Questionnaire

The Equipment

1) How would you describe the quality of the audio connection?

Very good	☐	Comments
Good	☐	
OK	☐	
Not very good	☐	
Poor	☐	

2) How would you describe the quality of the video image?

Very good	☐	Comments
Good	☐	
OK	☐	
Not very good	☐	
Poor	☐	

3) How would you describe using the pen and tablet?

Very easy to use	☐	Comments
Easy to use	☐	
Reasonably easy to use	☐	
Not very easy to use	☐	
Difficult to use	☐	

4) How would you describe making the computer connection with the tutor?

- Very easy ☐
- Easy ☐
- Reasonably easy ☐
- Difficult ☐
- Very difficult ☐

Comments

5) Overall how easy did you find it to use the equipment?

- Very easy ☐
- Easy ☐
- Reasonably easy ☐
- Difficult ☐
- Very difficult ☐

Comments

6) How would you rate the location of the equipment?

- Poor ☐
- Not very good ☐
- OK ☐
- Good ☐
- Very good ☐

Comments

7) Are there any ways in which you think the equipment or its location could be improved?

8) What did you like about using the equipment?

9) What didn't you like about using the equipment?

The tutorials

10) Please list what you see as the differences between DVC tutorials and face-to-face tutorials

11) Do you think there is any significant difference between **using** a whiteboard and paper?

Yes ☐ Comments

No ☐

12) How does using a whiteboard compare to using paper?

Much better ☐ Comments

Better ☐

About the same ☐

Not as good ☐

Much worse ☐

13) Overall how would you describe a tutorial using the computer compared to face-to-face?

Much more intense ☐ Comments

More intense ☐

About the same ☐

Not as intense ☐

Much less intense ☐

14) Please suggest ways in which you think DVC tutorials could be improved.

15) How much do you think you learnt in an average DVC tutorial compared with a face-to-face one?

Much less ☐ Comments

Not as much ☐

About the same ☐

more ☐

Much more ☐

16) What did you like about DVC tutorials?

17) What didn't you like about DVC tutorials?

18) Which type of tutorial do you prefer?

Face-to-face ☐ Why?

DVC ☐

19) Any other comments you would like to make.

Thank you for your help

Appendix 3 – Attitude Test

STATEMENT	strongly agree	agree	not sure	disagree	strongly disagree
I enjoy maths					
a good grade at GCSE maths will help me to get a good job					
Universities should require all students to have a grade C or better at GCSE maths					
maths is difficult					
all teachers need to be good at maths					
I'm **<u>NOT</u>** interested in maths					
maths helps you think clearly					
maths is too difficult for many people					
without good teaching of maths at an early age it is very difficult to become good at it					
maths is **<u>NOT</u>** interesting					
solving problems can be fun					
maths is something I **<u>ONLY</u>** do because I have to					

The following shows the scoring applied to the questionnaires.

STATEMENT	Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
I enjoy maths	2	1	0	-1	-2
A good grade at GCSE maths will help me to get a good job	2	1	0	-1	-2
Universities should require all students To have a grade C or better at GCSE maths	2	1	0	-1	-2
Maths is difficult	-2	-1	0	1	2
All teachers need to be good at maths	2	1	0	-1	-2
I'm **NOT** interested in maths	-2	-1	0	1	2
Maths helps you think clearly	2	1	0	-1	-2
Maths is too difficult for many people	-2	-1	0	1	2
Without good teaching of maths at an early age it is very difficult to become good at it	2	1	0	-1	-2
Maths is **NOT** interesting	-2	-1	0	1	2
Solving problems can be fun	2	1	0	-1	-2
Maths is something I **ONLY** do because I have to	-2	-1	0	1	2

Appendix 4 - Definitions and Notation used in Discourse Analysis

[ ] Exchange boundaries

( ) Optional items

→ Predicts a following utterance and is therefore not-terminal

← Is predicted by a preceding item and is therefore non-initial in an exchange

I **Initiate** - This will typically be a question, which predicts (requires an answer).

R **Respond** – This is predicted by an Initiate and will typically be an answer to a question.

R/I **Respond/Initiate** - This could take the form of an answer from a student followed by a question back to the teacher or a response from a student that requires an obligatory response from the teacher.

F **Feedback** – Differs from respond in that it is typically a short utterance such as 'yes',' right', or 'ok'. Hence Stubbs may classify what Laurillard describes as feedback from the tutor as a response, this being determined by the nature of the feedback.

Ir **Re-initiate** - These are non-initial and predict and could be for example a follow up question by a tutor.

Inf **Inform** – does not predict response and might for example take the form of a lecture.

Appendix 5 – Equipment used for the Research

Tablet –	Genius Easypen
DVC Hardware & software –	Intel ProShare Video System 500, version 5.1 with netmeeting version 2.11
Computer -	Intel Celeron Processor with 192m MB RAM
Operating System -	Windows 98 Second Edition

Appendix 6 – Initial Assessment Test

EXETER COLLEGE - MATHS GCSE WORKSHOPS

Initial Assessment

Please complete the details below and then do the two short tests and questionnaire that follow.

You have 60 mins to do the tests.
The tests are to be done without a calculator.
The questions get progressively more difficult.
Answer as many questions as possible .

SURNAME .... **First Names**.....................................
Block capitals please

Last School/College attended...

Grade for GCSE maths............. **Level GCSE maths sat at.(fnd/int/higher)**..................

---

for staff use:

test 1 score...................... test 2 score........................

Comments..
....
....
....

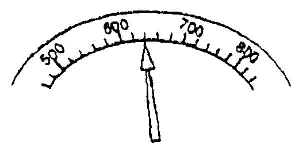
Test 1 - Potential

1. What do you think is the next number in this sequence?

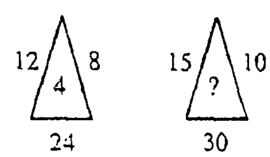
   25 20 15 10

2. A woman has £100. She earns £50 more and spends £70. How much does she have now?

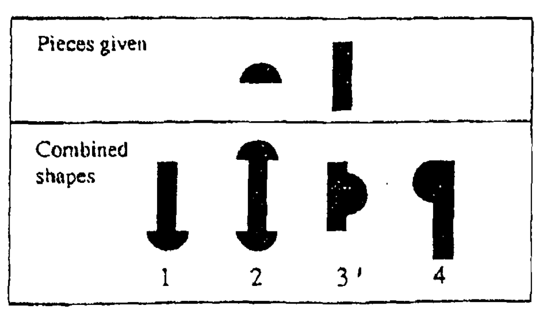
3. To what number is the arrow pointing?



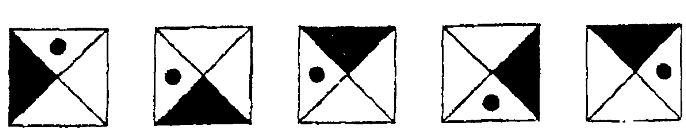
4. What do you think is the missing number?



5. Give the number(s) of any of the shapes shown below which can be made from the two pieces given.
   (Each piece should be used only once.)



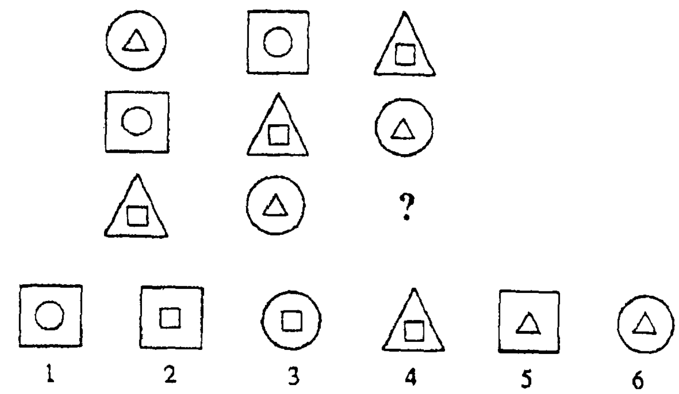
6. Which is the odd one out?



1 2 3 4 5

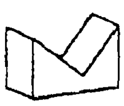
CIMT / Kassel / Potential / Aug 1995

7. Give the number of the shape from those below which completes the pattern.



8. I think of a number. I double it and take away 17. The answer is 45. What was the number?

9. How many surfaces has the solid shown opposite?



10. The five letters A, B, C, D, E are to be put into a 5 x 5 grid. Each row and each column must contain each letter exactly once.

The first three rows are given.

Complete the grid with two more rows.

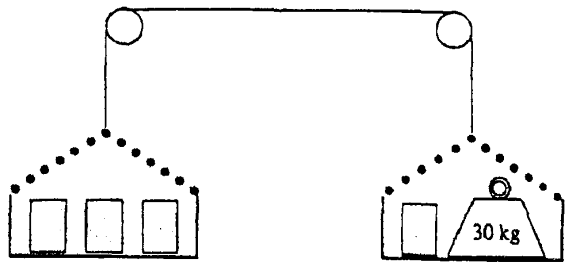
A	B	C	D	E
C	A	D	E	B
B	C	E	A	D

11. There are four bags containing black and white counters.

Bag A	:	12 black	and	4 white
Bag B	:	20 black	and	20 white
Bag C	:	20 black	and	10 white
Bag D	:	12 black	and	6 white

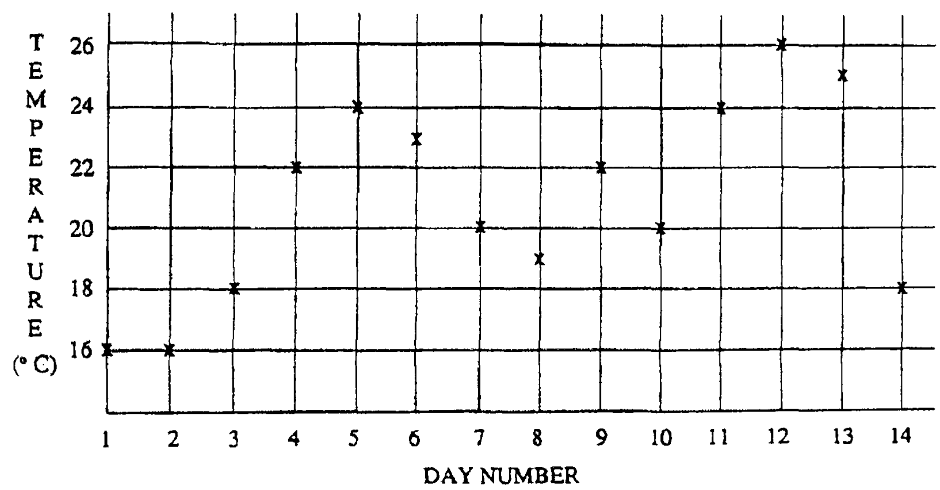
You have to take out one counter from a bag (with your eyes closed).
Which bag gives you the best chance of getting a black counter?

12. Each sack weighs the same, and the scales balance.
What does one sack weigh?



13. The diagram below shows the highest temperature each day during the first two weeks of July at a holiday resort.

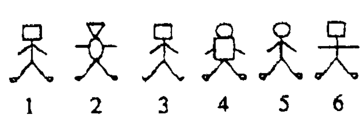
On how many days was the highest temperature at least 20°C?

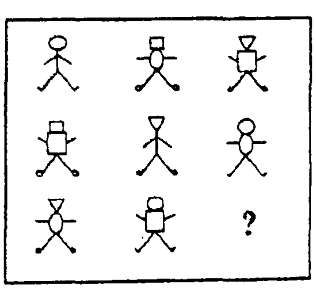


14. What do you think are the next two numbers in the sequence?

6 9 18 21 42 45

15. Give the number of the shape from those below which completes the pattern opposite.





Test 2 Numeracy

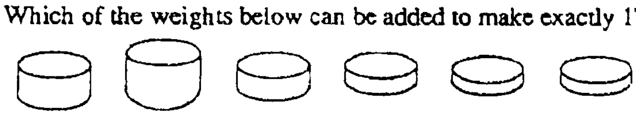
1. $4 \times 60 = ?$

2. 20 cards are shared out equally among 5 children.
How many cards does each child have?

3. A train leaves a station at 09.25 and takes 45 minutes to reach the next station. At what time does it arrive at the next station?

4. You buy two sweets costing 20 p and 23 p.
What is your change from 50 p?

5. Which of the weights below can be added to make exactly 17 kg?



5 kg   7 kg   4 kg   3 kg   2 kg   2 kg

6. What is a quarter of 80 m?

7. Tickets cost £4 each. How many can be bought for £15?

8. Find the cost of four books at £1.15 each.

9. Find 10% of 300 m.

10. What is 25% of 60 kg ?

11. $\frac{1}{2} + \frac{1}{4} = ?$

12. What is $\frac{1}{3}$ of 12 years?

13. $800 \div 40 = ?$

14. The temperature changes from $-4^\circ C$ to $7^\circ C$.
What is the increase in temperature?

15. Express 20% as a fraction.

16. Calculate $\frac{1}{10}$ of 4 m and express the answer in centimetres.

17. Pencils cost 15 p each. (a) How many can be bought for £2?

(b) How much change will there be?

(a)
(b)

18. Give a number to two decimal place, which lies between

122.257 and 122.263

19. Three lengths of curtain rail: 2 m, 2 m 30 cm and 3 m 55 cm, are cut from a rail of length 12 m. What length of rail is left?

20. $30 \times 650 = ?$

Appendix 7 - Outcomes for students Receiving Learning Support

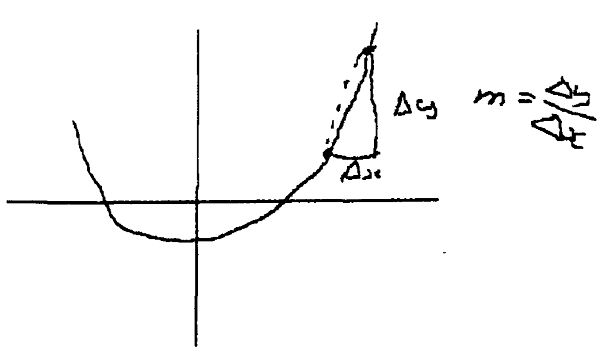
Name	Grade on entry	Final grade	school	Face-to-face Tutorials (hrs)	DVC tutorials (hrs)	Comments
J Ch	D	D	50	29		
J Co.	E	D	50		14	
I Do.	D	C	50	3	47	
A Ta	D	C	38	30	1	
C La	F	C	50		32	Over 2 years. L S yr 1 only
J Bi	D	C	38	36	46	Over 2 years
D Da	D	C	43		14	Sat exam yr after support
S St	D	C	52	1	19	
S Wi	D	C	62	7	24	
S Ke	D	D	62	17		
S Ma	none	B	43		25	
J An	E	Not sat	38	20		
J De	E	D	50	6		
H Pa	D	C	50		15	
K Ti	D	D	38	15		
P Ri	E	C	50	16		
A Sc	D	C	43	15		
S Ma	E	D	50	20		
C De	D	D	50	2		
S Ke	D	D	50	15		
S Je	E	D	50	14		
N Re	D	D	62	4		
K Wa	-	D	50	8		
R Bu	E	D	54	5		

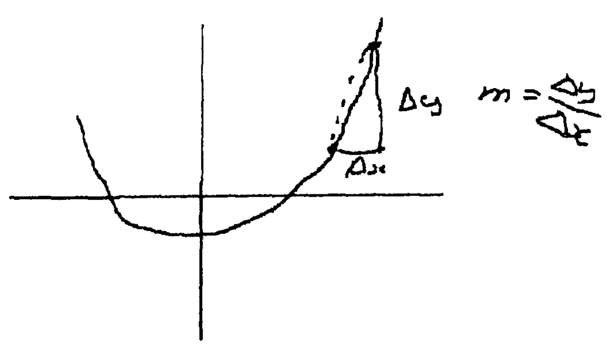
Appendix 8 – Student data used in the regression analysis

potential test	numeracy test	fnd lev	school	workshop hrs	attitude	learning support	mock
11	17	1.25	50	44	4	31	38
9	9	1.25	38	56	-6	29	22
12	21	1.25	43	90	13	25	62
13	19	1.25	52	90	-5	20	46
8	18	1.25	62	30	5	17	41
10	20	1.25	50	56	4	15	50
11	16	1.25	50	33	2	15	44
9	14	1	50	43	0	14	35
8	11	1	50	62	0	14	17
10	8	1.25	50	68	0	8	24
11	15	1.25	50	47	-4	6	25
8	15	1	54	53	0	5	44
8	16	1.25	50	41	-7	4	38
13	20	1.25	62	67	0	4	38
12	17	1.25	50	30	5	3	37
11	18	1.25	38	61	9	2	51
8	12	1.25	62	69	7	2	18
13	21	1.25	50	68	15	0	91
12	21	1.25	50	71	0	0	83
14	19	1.25	50	90	0	0	80
12	20	1.25	50	41	8	0	76
12	17	1.25	50	75	0	0	71
13	18	1.25	50	61	10	0	61
13	16	1.25	50	61	-8	0	61
11	19	1.25	27	61	9	0	60
12	18	1.25	27	32	-1	0	60
12	21	1.25	50	52	5	0	58
9	20	1.25	50	45	14	0	56
11	20	1.25	50	41	0	0	53
11	19	1.25	50	43	-2	0	52
10	20	1.25	62	78	-3	0	52
11	19	1.25	43	53	12	0	49
9	16	1.25	50	62	9	0	49
8	17	1.25	50	79	2	0	49
9	16	1.25	50	32	9	0	48
10	19	1.25	38	63	7	0	48
13	17	1	50	42	11	0	47
14	20	1	38	69	0	0	47
12	14	1.25	36	60	0	0	47
13	16	1.25	48	84	12	0	45
13	21	1.25	50	57	9	0	44

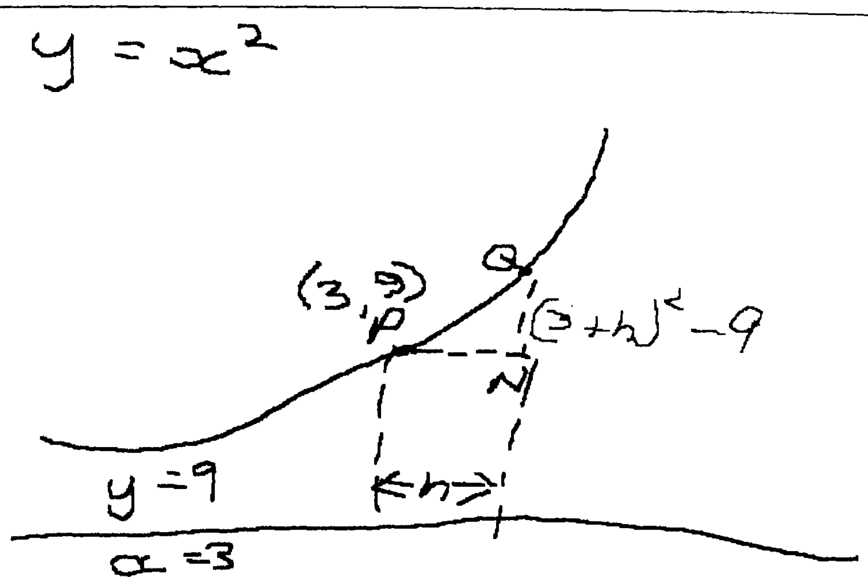
11	21	1	38	56	-1	0	44
12	15	1.25	52	40	9	0	42
11	13	1.25	50	61	-2	0	42
12	17	1.25	50	59	0	0	42
11	11	1.25	50	73	6	0	41
9	15	1.25	43	55	1	0	41
12	18	1.25	54	56	-4	0	41
8	17	1.25	50	73	0	0	41
13	15	1.25	52	46	10	0	40
12	10	1.25	50	53	0	0	40
12	19	1.25	48	57	10	0	39
12	19	1.25	62	48	1	0	39
8	14	1.25	50	76	6	0	38
12	19	1.25	30	70	0	0	38
12	18	1.25	43	54	0	0	38
12	17	1.25	43	77	6	0	37
13	14	1.25	38	77	1	0	37
10	15	1.25	50	71	0	0	36
11	13	1	48	84	11	0	33
8	16	1.25	52	50	5	0	33
10	13	1	43	75	3	0	33
10	14	1.25	50	57	0	0	33
13	15	1	38	53	6	0	31
12	11	1.25	30	73	9	0	30
11	15	1.25	52	44	-5	0	29
11	12	1.25	50	78	0	0	28
10	15	1.25	50	45	0	0	27
11	16	1.25	50	48	7	0	26
12	18	1.25	50	69	8	0	23
8	12	1	62	62	7	0	23
13	15	1	62	78	4	0	23
7	11	1.25	50	65	3	0	16
12	11	1	38	78	-4	0	16

Appendix 9 Transcripts from face-to-face and DVC tutorials

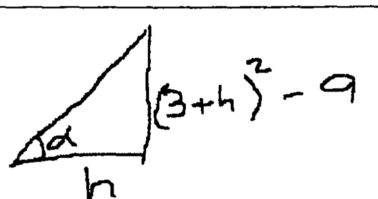
T	Here we go. The first student is. …………I'll place this down there. Right OK M……… off we go.
S	Okay right, I thought we would have a look at differentiation
T	Right
S	If that's okay
	……………………………………………………………………………………………… ..
T	Oh good, it's probably best. Right it's a bit of calculus today
S	Yeah right. So the whole point (interrupted)
T	You have just started that?
S	Yeah we have only had one lesson on it and a lot of that was spent talking about fourth dimensions and the universe and things like that. ***So the whole point of differentiation is as I understand it is to find the gradient of a point on a curve*** **[2]**
T	That's right.
S	Yeah and you do that by finding the gradient of a tangent that touches the point on the curve that you want.
T	That's right. Shall we draw something?
S	Yeah, you draw it Phil.
	
T	Basically you look at a point here and a point close to it, and essentially draw the straight line that joins the two, the way I have drawn this curve even makes it look like a straight line doesn't it?
S	Yes.
T	So if I were to say there's the line joining the two, I'll try and do a dotted line, you can work out the slope of that line.

S	Right yeah.
T	This height (interrupted).
S	And then it (interrupted).
T	That height divided by that height.
S	Yeah and then its, what's it?
T	It's basically the tan of the angle. Right very good ………
S	What I was going to say was the erm, lets just get rid of that, I understand that I think pretty much but its (interrupted)
T	This is your Δy isn't it, and that's your Δx .
S	And I understand that, I think. But we've also had a look at this idea of a limit, which I sort of found a bit more difficult. The example we used, I mean it's a bit difficult because I've got a bit of paper in front of me.
T	Well just write on here what you've got, that's the easiest way as I haven't got the paper.
	………………………………………………………………………………………
	
T	Let's draw it again
S	Okay go for it.
T	Axis, axis.
S	Is there not an undo function or something?
T	I'll do a better curve this time and then you have got two points here, so a point there and a point here. Then we'll try and look at the line joining it. Just as bad as before isn't it really?
S	I suppose you get better with practice.

T	You wrote down something you wrote down m = Δy over Δx So you might as well do it again.
S	Okay right, bit of an angle but there you go.
T	The slope is an angle isn't it?
S	Yeah right so we go onto a new page.
T	So what you do is erm.



T	Right so the example I've got, is that what you've got?
S	Yes.
T	Right so I'll do you a bit of curve, not a very good curve, but there you go. Right so you've got a point, or points. We've got point Q, and Q's the limit, and point P and you've got your little triangle there, and what else have we got? Put a line underneath here. Has he got any equations or just a general?
S	Yes the equation is (writes $y = x^2$) okay.
T	I thought it might be something like that. I had a feeling it might be. Yeah Ok right.
T	Right okay.
S	So h is the............what the x distance between P and Q.
T	Yes so then P (interrupted).
S	So where is P, has P gone up.
T	P is fixed, actually do you have your textbook; no you don't have the pure maths book.
S	No I haven't got it with me.
	All I know is y = 9, so I think x= 3.

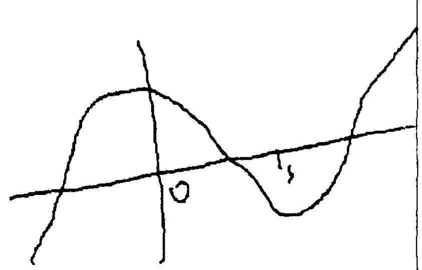
T	Ok.
S	You want to know the co-ordinates of.
T	So that is your Q?
S	No that's just for the – I'm not sure what that is for.
T	***Usually what you do is that say P is the point you were just talking about (3,9). Then Q will be a little bit further away from it. Like 3.1*** **[3]**
S	Right
T	Is that what you were going to do?
S	***Erm yeah its what I was going to do, the delta Y is $(3 + h)^2$ - 9 is what I have got down here*** **[4]**
T	That's fine
	....
S	So the thing is I don't understand what actually is a limit then.
T	What you do then is you, let me just draw that little bit of triangle in again.
S	Or do you want to go back to the page before.
	 $m = \frac{(3+h)^2-9}{h}$ $(3+h)(3+h)$ $9+3h+3h+h^2$ $\frac{h^2+6h}{\cancel{h}}$ $\quad \frac{\cancel{h}(6+h)}{\cancel{h}}$ $h+6$ $\quad 6+h$ $m=6$
T	No, just do it separately, this is the one that was $(3 + h)^2$ - 9. This is h, ok.
S	Yes.
T	Your approximation is basically the tan of that angle that's your gradient, so m is $(3 + h)^2 - 9$ all divided by h.

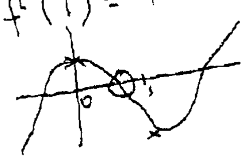
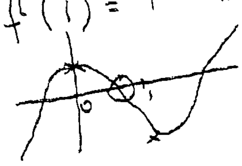
S	Yes that what I've got.
T	It's the y value divided by the x value. The change in y (INTERRUPTED).
S	Yes but is that for, is that for… (INTERRUPTED).
T	This triangle here?
S	Yeah but if (INTERRUPTED).
T	If you call that point N.
S	That's for the triangle but that's not for (INTERRUPTED).
T	The idea (INTERRUPTED).
S	We're trying to find the gradient at point P.
T	That's right The idea, what will happen is that Q will get closer and closer to P. Your h at the moment is anything, just any old length, could be 1,0.1, 0.01.
S	Yes, In the book it says where h is a low value.
T	***Right Ok, but what is going to happen is we will look what it is for a general h, when we know it is going to be small and then eventually let Q get closer and closer and closer to P, in other words let h get smaller. That's the limiting process; you've got to picture h getting tinier and tinier. As Q gets closer to P right, then this triangle becomes, the line joining P to Q will eventually become part of the curve. It will be so close that the straight line is almost indistinguishable from the arc of PQ on the curve.*** **[1]**
S	Right. Okay.
T	***What you need to do is expand that, this thing on the top,*** **[6]**…flash now put this in. I want you to expand this bit here.
S	Right yeah.
T	Tell me when.
S	Only I've got it here.
T	You've got it there then that's cheating (LOTS OF LAUGHTER).
S	I can do it, I mean its just expanding brackets.
T	Write it down anyway
S	***Right You've got $(3+h)^2$ so your going to get $9 + 3h + 3h + h^2$. So then you get overall because the minus 9 and the plus 9 will cancel out - you will get $h^2 + 6h$, I think.*** **[7]**
T	***Yes so the top is $h^2 + 6h$ that's fine. The 9s have gone; so don't forget to divide by h as well.*** **[8]**

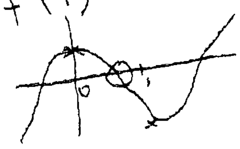
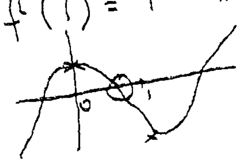
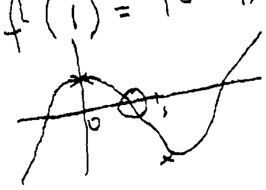
S	All right, then when you …….so then that's all over h, so then.
T	What is that going to be.
S	*That's going to cancel out with that.* **[9]**
T	So that becomes just h.
S	Then it will be h +, is it 6h or just h or just 6.
T	6h divided by h isn't it. So that h is going to divide both of these terms.
S	The thing is in my book, the way they've done it is that they've got h.
T	That's right, that's with the 6.
S	6+h.
T	All divided by.
S	h and then there's that and that.
T	That's right that's good, 6 + h.
S	Yeah
T	Right. As you let h get smaller and smaller and smaller, what's going to happen of course is that gets closer to 6, so in fact the gradient at that point is going to be 6.
S	So m equals 6. Can you ever say that for definite?
T	Yes there is a limiting process. So when h equals nought, which is basically when it is right on top of the point, its going to be 6 so you know its 6.
S	Excellent, I get it now.

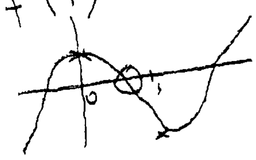
Figure 9.1: Part of transcript from audio only recording

Participant	Characteristic of Conversationa	Dialogue		Discourse analysis verbal	Discourse analysis non- verbal	Exchange unit Number
S		Can we do fixed point iteration. I can't remember how to go through one. I've got an equation here it is $x^3 - 7x + 3 = 0$. That one. They gave us that as an example in this book. So if we can just go through how to do it	$x^3 - 7x + 3 = 0$	[I	I	1
T		OK Have you located one of the solutions?		R/I		
S		Yes		R]		
T	1	If you think of that as being f(x). that is some function of x isn't it?		[I		2
S		Yes		R		
T	6	You know what a cubic looks like roughly. What happens if you work out f(0)	$x^3 - 7x + 3 = 0 = f(x$ $f(0) = ?$	Ir	Ir	
S	7	That's 0 cubed minus 7 times 0 plus 3; that's 3	$x^3 - 7x + 3 = 0 = f(x$ $f(0) = ? = +3$	R	R	
T	6	OK what's the value of f(1)		Ir		

S	7	So that's $1^3-7\times1+3=$ That's –4; no sorry –3, I forgot to add the 1 from 1^3	$x^3-7x+3=0 = f(x)$ $f(0)=?=+3$ $f(1)=1^3-7\times1+3=-3$ *student corrects error by writing over it*	R	R	
T	8	That's right The main thing is 0 is +ve and 1 is –ve. What does that tell you?		F] [Inf/ I		
S	4	It goes down		R		3
T	8 3	Yes. but more than that its got to cross the axis between 0 and 1		F] [Inf		4
S		Yes		F		
T	3	In other words the solution of f(x)=0 must be somewhere between 0 and 1, you have always got to do this with fixed point iteration; you've got to know roughly what the answer is. All we know is that it is between 0 and 1. Just because it is +3 and –3 it doesn't mean it is a half, unfortunately, it doesn't work that way, but we know it is somewhere between 0 and 1 Let me just draw a picture of that. What it means is that we know that at 0 it goes through 3 and at 1 it goes through –3 . The graph might have come up here like this and up there again ,	$x^3-7x+3=0 = f(x)$ $f(0)=?=+3$ $f(1)=1^3-7\times1+3=-3$ 	Inf Inf	 Inf	

		we are trying to find that point, because we're trying to find where y=0. Because we have found that is is positive and that is negative, we know that something happens between the two of them. So you are always looking for that to try and locate the root	$x^3-7x+3=0 = f(x)$ $f(0)=? = +3$ $f(1) = 1^3-7\times1+3 = -3$	Inf	Inf	
		So we have got to go back to your equation at the top of the page and its fixed point iteration you are doing . You've got to rearrange that to make it 'x' equals to start with .				
		There are lots of different ways you can do it One way to do it would be to take this 7x and move it to this side. Then the x^3+3 would stay where it is and the 7x would go over there	$x^3-7x+3=0 = f(x)$ $f(0)=? = +3$ $f(1) = 1^3-7\times1+3 = -3$  $x = g(x)$	Inf	Inf	
S		Equals 7x, yes		F]		
T		Would you write that down		[I		5
S		$x^3+3=7x$	$x^3-7x+3=0 = f(x)$ $f(0)=? = +3$ $f(1) = 1^3-7\times1+3 = -3$  $x = g(x)$ $x^3+3=7x$	R	R	
T	6	OK, now how can we get that to be x equals? You've got 7x at the moment, what are you going to divide by?		F/Ir	F	
S		Pass. I'm confused because I've got two lots of x`s		R		

T	8 3	Yes that's right, that's why it's called x = g(x), the whole thing is written at the fixed point as x = g(x) so you get 'x' on the left hand side and anything you like on the right hand side in terms of x; which is just another way of writing the equation		**F/ Inf**	
S		Oh right		**F**	
T	8	We don't want 7x like we've got here	$x^3 - 7x + 3 = 0 = f(x)$ $f(0) = ? = +3$ $f(1) = 1^3 - 7\times 1 + 3 = -3$  $x = g(x)$ $x^3 + 3 = 7x$ ***tutor rings the 7x to indicate what he wants the student to address***	**Inf**	**Ir**
S	9	So I would say x = 7x –3 cube rooted	$x^3 - 7x + 3 = 0 = f(x)$ $f(0) = ? = +3$ $f(1) = 1^3 - 7\times 1 + 3 = -3$  $x = g(x)$ $x^3 + 3 = 7x$ $x = \sqrt[3]{7x-3}$	**R**	**R**
T	8	Yes that's one way of writing it, there is an easier way. Another way would be this. You've got $x^3 + 3 = 7x$, so you could say $x = \dfrac{x^3+3}{7}$	$x^3 - 7x + 3 = 0 = f(x)$ $f(0) = ? = +3$ $f(1) = 1^3 - 7\times 1 + 3 = -3$  $x = g(x$ $x^3 + 3 = 7x$ $x = \frac{x^3+3}{7}$ $x = \sqrt[3]{7x-3}$	**F/ Inf**	**Inf**

S		Right		F		
T	3	These two, I'll put an'or' in there. Both of these are OK, they are both the same as the equation. They are both different ways of writing it as $x = g(x)$.Now sometimes some of these work and sometimes they don't. The only way you're going to work out is if you keep trying with it	$x^3-7x+3=0 = f(x)$ $f(0) = ? =+3$ $f(1) = 1^3-7\times1+3 = -3$  $x = g(x$ $x^3+3 = 7x$ $x = \frac{x^3+3}{7}$ $x = \sqrt[3]{7x-3}$	Inf	Inf	
S		Right. When they say sometimes find 'x' what do you have to work on with this?		F] [I		
T	3	You've got to have a guess to start with, that's why we did that little game to start with up here		R/ Inf		6
S		Right		F]		
T	3	So we know the root is somewhere between 0 and 1 . You've got to have an initial stab at the roots. The idea of this is that it will keep improving your guess. That's what you hope		[Inf]		7
S	4	On the fixed point though don't we draw a line through the origin or is it through the point we are at and then start drawing steps. Where does that come into it?		[I		8
T	3	That's a way of seeing it pictorially		R		
S	4	Right but you've got to work it out numerically first		F/ Ir		
T	3	Yes you got to work it out first, you have got to see how things work first		R/ Inf		

S		Right I see		F]		
T		Lets look at an easier one than this to start with		[Inf]		9

Figure 9.2: Transcript of DVC tutorial 6

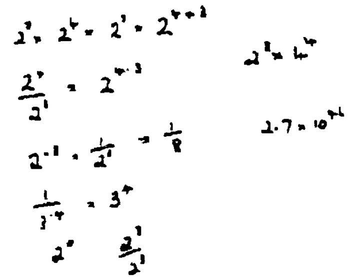
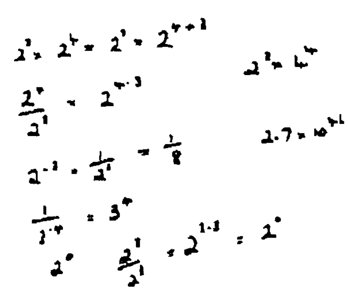
Participant	Characteristic	Dialogue		Discourse analysis verbal	Discourse analysis non- verbal	Exchange unit Number
S		Now can we go onto to look at these? I'm kind of OK	*Student shows tutor sheet of questions on indices*	[I	[I	1
T	 6	Right You've really got to know what the rules of indices are. If you have got $2^3 \times 2^4$, you probably know what that is?	$2^3 \times 2^4$	R/ Inf] [I		2
S	7	2^7		R		
T	8 1 6	2^7 and the rule there is if you have the same number and different indices and you are multiplying, you add them together. Likewise if you have $\frac{2^4}{2^3}$ what would that be ?	$2^3 \times 2^4 = 2^7 = 2^{4+3}$ $2^3 \times 2^4 = 2^7 = 2^{4+3}$ $\frac{2^4}{2^3} =$	F/ Inf Ir	F/ Inf Ir	
S	7	Just 2		R		

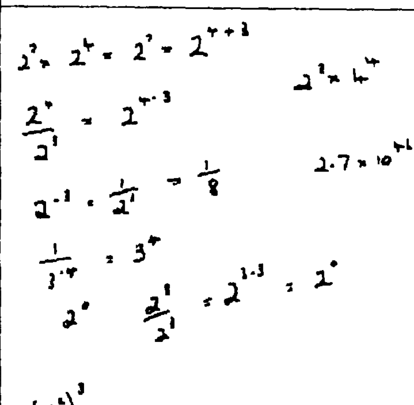
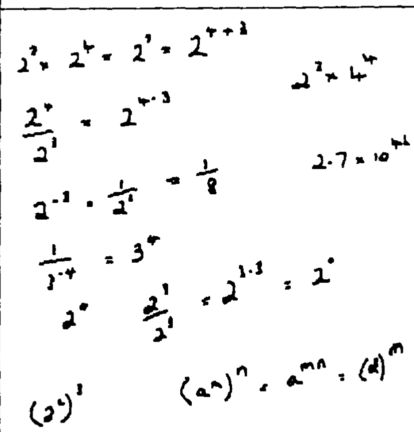
T	8	2, It would be 2^1 , 2^{4-3} ,	$2^3 \times 2^4 = 2^7 = 2^{4+3}$ $\frac{2^4}{2^3} = 2^{4-3}$	F/	F	
		basically that one comes from 4+3	*Pointing to work page*	Inf	Inf	
		whereas this one comes from 4-3	*Pointing to work page*	Inf	Inf]	
	6	What about if you had 2^{-3}, what does that mean	$2^3 \times 2^4 = 2^7 = 2^{4+3}$ $\frac{2^4}{2^3} = 2^{4-3}$ 2^{-3}	[I	[I	3
S	7	This is where I'm getting confused. Claire said that the minus meant one over something		R		
T	8 1	That's right, exactly so the minus means it's in the wrong place so the number can either be on the top line or the bottom, the numerator or the denominator now this one is on the top which means it should be on the bottom. The power is still 3, the minus tells you it is in the wrong place so in fact that should be $\frac{1}{2^3}$, its downstairs rather than upstairs ; likewise if you write $\frac{1}{3^{-4}}$ then you say well, this 3 is on the bottom and it has a minus power, so it ought to be on the top.	*Pointing at work page* $2^3 \times 2^4 = 2^7 = 2^{4+3}$ $\frac{2^4}{2^3} = 2^{4-3}$ $2^{-3} = \frac{1}{2^3}$ --- $2^3 \times 2^4 = 2^7 = 2^{4+3}$ $\frac{2^4}{2^3} = 2^{4-3}$ $2^{-3} = \frac{1}{2^3}$ $\frac{1}{3^{-4}}$	F/ Inf	Inf	

S		Alright		F		
T	1	So that is the same as 3^{+4}, it still 3^4 but the minus tells us its in the wrong place. So if its on the top it should be on the bottom and if it's on the bottom it should be on the top.	$2^3 \times 2^4 = 2^7 = 2^{4+3}$ $\frac{2^4}{2^3} = 2^{4-3}$ $2^{-3} = \frac{1}{2^3}$ $\frac{1}{3^{-4}} = 3^4$	Inf]	Inf]	
S		So you would write the answer as that?		[I		
T	6	What's two cubed		R/Ir		
S	7	eight		R		
T	8 1	8, Right so its $\frac{1}{8}$, that's a very strange way of writing that 2^{-3} is an equally good way of writing $\frac{1}{8}$. So you have lots of ways of writing it you could write as a decimal, zero point what ever it is, one two five, or you can write it as that, they are both exactly the same number this is just a way of writing it in terms of powers of two	$2^3 \times 2^4 = 2^7 = 2^{4+3}$ $\frac{2^4}{2^3} = 2^{4-3}$ $2^{-3} = \frac{1}{2^3} = \frac{1}{8}$ $\frac{1}{3^{-4}} = 3^4$ *Pointing to work page*	F/ Inf]	Inf]	4
S		Just to confuse us?		[I		5
T	 6	Just to confuse you, absolutely. That one 4^{-2} that 4 is at the top so what is the value of that one?	*Pointing at students question paper*	R] [I	 [I	6
S	7	That's one over four to the power two		R		

T	8	That's good. What's four to the power 2		F/ Ir		
S	9	Sixteen, $\frac{1}{16}$		R		
T	8	Right so its $\frac{1}{16}$		F]		
S		So when its not minus		[I		
T	3	Right if they were multiplied together you add them. they've got to be the same number $2^3 \times 3^4$, no you can't do that, its got to be the same number, to do that	*Pointing to work page*	R/ Inf	Inf	7
S	4	Then you would just leave it as it was?		[I		
T	3	That's right, it depends on the numbers, if it was $2^3 \times 4^4$ because there is a link between two and four, you can do it. We'll come to that later on.	$2^3 \times 2^4 = 2^7 = 2^{4+3}$ $\quad 2^3 \times 4^4$ $\frac{2^4}{2^3} = 2^{4-3}$ $2^{-3} = \frac{1}{2^3} = \frac{1}{8}$ $\frac{1}{3^{-4}} = 3^4$	R/ Inf]	Inf]	8
S	4	But you can obviously with figures multiply them out ?	*Pointing to work page*	[I	[Inf	
T	3	Yes you just get a number. Sometimes it is better to write it in terms of powers because the number might be that long. If you've got 2^{25} for example it is a neater way of writing it,. If you put 2^{25} into your calculator it would go off the end of your calculator whereas 2^{25} is exact.		R/ Inf]	Inf]	9
	6	Put it into your calculator,		[I		10

S	7		*Puts into calculator*		R
T	8 6	oh it will do it. Put 2^{35} into your calculator. there will be a stage where it goes off your screen.		F/ Ir Inf	
S	7		*Puts into calculator*		R
T	8 3	Its given you that times ten to the power ten which means it is not exact, where as 2^{35} is an exact number, this is an exact number, this is an approximation to it. So when you've got numbers like that you might be better off to leave it in that form you often write numbers like this 2.7×10^{46}, that's a very big number but you don't want to write down two seven 0 0 0 for ever; that's a neat way of writing it.	$2^1 \times 2^4 = 2^5 = 2^{4+1}$ $2^3 \times 4^4$ $\frac{2^4}{2^3} = 2^{4-3}$ $2^{-3} = \frac{1}{2^3} = \frac{1}{8}$ 2.7×10^{46} $\frac{1}{3^{-4}} = 3^4$	F/ Inf	Inf]
T	3 6	There's one other thing you need to know, you've got the adding them if its multiplying subtracting them if you are dividing them. We now understand what the minus sign means. You see that minus sign there we did 4 minus 3 there because it was downstairs you can see a hint of where its come from there. What about 2^0	*Pointing at work sheet* $2^1 \times 2^4 = 2^5 = 2^{4+1}$ $2^3 \times 4^4$ $\frac{2^4}{2^3} = 2^{4-3}$ $2^{-3} = \frac{1}{2^3} = \frac{1}{8}$ 2.7×10^{46} $\frac{1}{3^{-4}} = 3^4$ 2^0	[Inf I	[Inf I
S	7	That's 1		R	
T	8	That's 1 why is it 1		F/Ir	

S	4	I don't know why I just know it is. She said anything to the power zero is 1.		R	
T	6	Right so how would you work that out $\frac{2^3}{2^3}$		F/Ir	Inf
S	7	That's one surely		R	
T	8	That's one because it's the same number on the top and bottom but think about it in terms of indices The way we did before up here	*Pointing at work sheet*	F/ Inf/ Ir	
S	9	Two to the power 3 plus 3 or minus 3		R	
T	8	2^{3-3} because you are dividing Which of course is?		F Inf/ Ir	
S	9	2^0		R	
T	8 3	2^0, that's where it comes from you got exactly the same number on the top and the bottom when you subtract the two you always get nought so what ever that number is it will always be something to the power zero if you do it in your calculator you check it		F/ Inf/ Ir	
S		I've tried it		R	
T	 6	That's right, say 65 to the power of nought is 1 now try nought to the power 1, sorry nought to the power nought	*Typing into the calculator*	F/ Inf/ Ir	
S	7	nought to the power nought	*Typing it into calculator*	R	R

T	8 3	It does not like it. You can get as close as you like to nought it's a bit like taking the log of nought; we haven't come across logs yet. So you have to be careful with extremes like that. So basically any positive numbers raised to the power of nought is equal to one. It is always useful to see where it has come from. You can argue that to see where it has come from		F/ Inf]		
S		Suddenly questions creep in like this	*Pointing at question sheet*	[I	[I	
T	 1	Yes right then you get this sort of thing $(2^2)^3$		R/ Inf	Inf	1 2
S		Yes I was just going to say there's something like that here	*Pointing at question sheet*	F]	F]	
	1 6	In general $(a^m)^n = a^{mn} = (a^n)^m$ What does $(2^2)^3$ mean		[Inf/ I	Inf	1 3
S	7	$2^2 \times 2^2 \times 2^2$		R		

T	8	Good $2^2 \times 2^2 \times 2^2$. What's the answer	*Writing it down* $2^3 \times 2^4 = 2^7 = 2^{4+3}$ $2^2 \times 4^4$ $\frac{2^4}{2^3} = 2^{4-3}$ $2.7 \times 10^{+6}$ $2^{-3} = \frac{1}{2^3} = \frac{1}{8}$ $\frac{1}{3^{-4}} = 3^4$ 2^0 $\frac{2^1}{2^1} = 2^{1-1} = 2^0$ $(2^2)^3$ $(a^m)^n = a^{mn} = (a)^m$ $2^2 \times 2^2 \times 2^2$	F Ir …]		

Figure 9.3: Transcript from face-to-face tutorial 9

Participant	Characteristic	Dialogue		Discourse analysis verbal	Discourse analysis non- verbal	Exchange Number
S		I would like to do from 7 onwards	*Pointing at exercise sheet on factorising polynomials* $f(x) = x^3 - 3x^2 - 7x + 12$	[Inf	Inf]	1
T		What have you got to do? Fully factorise; right ok have you done that		[I		2
S		I think so this is easy but I don't know how to find the first factor in this question		R/Ir		
T	1	You just try 1, -1, 2 -2		R]		
S		I've done that but it seems weird to me like its not right, if it's 1		[Inf		3

T		It's not going to be 1, I shouldn't think		F]		
S	7	That's 1-3-7+2	$f(x) = x^3 - 3x^2 - 7x + 12$ $= 1 - 3 - 7 + 12$	[Inf	Inf	4
T	8	+12		F]		
S	9	+12		[Inf]		5
T	8	That's not nought is it? It's not zero; so try 2		[Inf]		6
S	7	2 cubed is 8, yeh?		[I		7
T	8	Yes		R]		
S	7	Minus 8 squared		[Inf		8
T	8	No its not that, it's 2 squared		F]		
S	9	2squared is 4; 12		[Inf		9
T	8	Right		F]		
S	7	Minus 14 plus 12	$f(x) = x^3 - 3x^2 - 7x + 12$ $= 1 - 3 - 7 + 12$ $8 - 12 - 14 + 12$	[Inf		10
T	8	Yes		F]		
S		Its not right?		[I		11
T	8	Its still negative isn't it. Is it negative or positive. That's positive isn't it	*Pointing at worksheet*	R/Ir		

S	9	Yes		R]		
T	6	And that is?	*Pointing to the first calculation*	[I		12
S	7	Negative		R]		
T	8 8 6	So there is a root between 1 and 2, but we shan't be able to find that one yet Have you tried looking at these numbers here to see if some combination of them works; that 20 ,30, 46; - try 3	*Pointing at previous calculations*	[Inf [I]* [Inf]	Inf]	13 14 15
S	7	3 cubed, 27		[Inf		16
T	8	yes		F]		
S	7	Minus 3 squared nine, 27 minus 21	$f(x) = x^3 - 3x^2 - 7x + 12$ $= 1 - 3 - 7 + 12$ $8 - 12 - 14 + 12$ $27 - 27 - 21 + 12$	[Inf	Inf	17
T	8	Yes plus 12. That's still not zero, strange. Minus 3 x squared minus 7x plus 12.	*Tutor checks students working and the original question on the sheet*	F	F]	
S		I've tried a lot even the minus numbers		[Inf]		18
T		have you tried 4?		[I		19
S		I've tried 4 as well		R		
T	6	Right try 4; 4 cubed is?		F/Ir		
S	7	4 cubed; 4 squared -16, times 4 is 64,16 times 3 is 48		R		

T	8	Yes ; 7 fours?		F/Ir		
S	7	7 fours; 28		R		
T	8	Right 28 +12 . lets try that one		F/Ir		
S		Right		R		
T	6	. 64 plus 12 makes		Ir		
S	7	72		R		
T	8	76; put it in your calculator if you can't do it		F/Ir		
S	9	I can do it; 48 plus 28, 76; Its zero	$f(x) = x^3 - 3x^2 - 7x + 12$ $= 1 - 3 - 7 + 12$ $8 - 12 - 14 + 12$ $27 - 27 - 21 + 12$ $64 - 48 - 28 + 12$ $= 0 \quad f(4)$	R	R	
T	8	You didn't go far enough. Usually they make it easier, in the exam they would tell you to work out f(1), f(2) or they give you a hint		F]		
S		I was losing my confidence because I couldn't find it		[Inf]		20

Figure 9.4: Transcript from face-to-face tutorial 10

Participant	Characteristic	Dialogue		Discourse analysis verbal	Discourse analysis non- verbal	Exchange Number
S		We can do something on polynomials.				1
		Use Pascal's triangle to expand $(1+x)^7$. Let me try it Ok.	$(1+x)^7$			
		(some help given to the student on the tools in the whiteboard)				
	7	So basically its	*Student starts writing the expansion but without the coefficients*	[Inf	Inf]	
T	8	You've forgot something		[I		2
S	9	Oh yes, let me think; I remember the Pascal triangle I'll do that at the end		R/Ir		
T	8	No you can't do it at the end you've got to put it in each term.		R]		
S	9	OK I'll just do it again.	***Students deletes what she has written***	[Inf		3
		So its 1^7 And the Pascal triangle for 7 is is one, something something, something let me draw a little triangle	***Student starts writing expansion again***	Inf]	Inf]	
T	8	Its 7 choose something, isn't it?		[I		4

S	9	Yes, 7 choose 6		R		
T	8	7 choose 6 that's right		F]		
S	7		***Student writes first two terms***		[Inf	5
T	8	Yes……….Right		F]		
S	7	That's bad, Wait let me do it again	***Student realises third term is wrong and erases it and then resumes writing***	[Inf	[Inf	6
T	8	Yes OK. You're getting the hang of it		F]		
S		Yes, obviously		[Inf]		7
T		I'm getting tired here.(reference to the time being taken by the student to write it down)		[Inf]		8
S		No wait I haven't finished yet I'm nearly done	$1^7 + {}^7C_6 1^6 x + {}^7C_5 1^5 x^2 + {}^7C_4 1^4 x^3$ $+ {}^7C_3 1^3 x^4 + {}^7C_2 1^2 x^5 + {}^7C_1 1 x^6 + x$	[Inf	[Inf	9
T	8	OK, Right that's good		F]		
S	7	And then let me see that is just 1^7 ,I'll just get my calculator out, 7C6 is 7, so it's plus 7x	***Student starts simplifying expansion***	[Inf	Inf]	10
		Are you doing this on your calculator now?		[I		
		Yes		R		11
T		Right ok		F]		
S	7	7x yes?		[I		12

	8	Right		R]		
S	7	Plus 7 choose, what's that, oh 5, that's 21?		[I		13
T	8	yes		R]		
S	7	And that's $21x^6$ no its x squared. Isn't it. If I'm not wrong 7C4		[I		14
T	8	35		R]		
S		Yes 35	$(1+x)^7$ $1^7 + {}^7C_6 1^6 x^1 + {}^7C_5 1^5 x^2 + {}^7C_4 1^4 x^3$ $+ {}^7C_3 1^3 x^4 + {}^7C_2 1^2 x^5 + {}^7C_1 1 x^6 + x$ $= 1 + 7x + 21x^2 + 35x^3$	[Inf	Inf]	15
T		That's a good guess		[I		16
S		No you just like done it		R]		
T	6	If 7 choose 4 is 35 what is 7C3		[I		17
S	7	It's 35		R		
T	8	35 as well		F]		
S	7	Yes and then its like Is that right?	*Writing the rest of the expansion down with just a 1 as the last term*	[Inf [I	Inf]	18 19
T	8	No the last term is wrong		R]		

S	9	Oh the last one is x to the power 7	***Student corrects the last term*** $(1+x)^7$ $1 + {}^7C_6 1 x + {}^7C_5 1 x^2 + {}^7C_4 1 x^3$ $+ {}^7C_3 1 x^4 + {}^7C_2 x^5 + {}^7C_1 x^6$ $= 1 + 7x + 21x^2 + 35x^3 + 35x^4$ $+ 21x^5 + 7x^6 + x^7$	**[Inf**	**Inf**	**20**
T	**8**	Fine that looks good		**F]**		

Figure 9.5:Transcript from DVC tutorial 7

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